VOLUME XXXIX NUMBER 4

BOTANICAL GAZETTE

APRIL, 1905

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. LX.

A NEW AMERICAN SPECIES OF WYNNEA.

ROLAND THAXTER.

(WITH PLATES IV AND V)

In the third volume of HOOKER'S *Journal of Botany and Kew Garden Miscellany* (1851) BERKELEY published a description without figures of a large and striking discomycetous fungus, distinguished by the possession of long ear- or spoon-shaped apothecia, arising in a fasciculate fashion from a well-developed common stem. This form, which was said to have been found abundantly on rotten wood near Darjeeling, India, he placed in the then very comprehensive genus Peziza, comparing it to *Peziza onotica* and *P. leporina*, and designating it as *P. macrotis*. Some years later, however, having received from Dr. CURTIS a closely related North American species collected by BOTTERI near Orizaba, Mexico, he was led to create the new genus Wynnea for the reception of these two forms (Jour. Linn. Soc. 9:1866), the Mexican species being used as the type under the name *Wynnea gigantea*. Both species were subsequently illustrated by COOKE in his *Micrographia*, the colors being no doubt guessed at from BERKELEY'S descriptions and from the dried specimens. *W. macrotis* is here said by COOKE to occur also in Mexico, but no authority for this statement is mentioned. During the forty years that have elapsed since the collection of *W. gigantea* by BOTTERI, there seems to have been no further mention of the occurrence of these or of other species of Wynnea, and in more recent years the genus has been consigned to the limbo of synonymy by SACCARDO in his *Sylloge*, where both species are included in the genus Midotis.

In the summer of 1888, a portion of which was spent by the writer in collecting fungi among the mountains of Tennessee and North Carolina, a species of Wynnea was found near Burbank, Tennessee, growing on the ground in rich woods, in a single locality; where several clusters of its long bluntly pointed, rabbit-ear-shaped dark brown apothecia were scattered in a limited space, each cluster borne on a well-defined stout stem emerging directly from the humus. The resemblance of this plant to COOKE'S figure of *Wynnea macrotis*, to which it closely corresponds in form and color, was so striking that it was assumed to be that species, despite certain differences in the size and appearance of the spores when fully mature, and in the absence of any authentic material of the Indian species for comparison it was so referred.

A second visit was made to the same region in 1896, and the Wynnea was again encountered, both at Burbank and at Cranberry, North Carolina; one of the specimens from the last-named locality being parasitized by a fine species of Syncephalis described in a former number of the GAZETTE (**24**:1. 1897) as *S. Wynneae*, the host being here recorded as *W. macrotis*. Having noticed, while gathering this material, that the stems appeared to have been broken from some attachment in every case, and not to have arisen like most humus Pezizae from an indefinite mycelium, a more careful examination was made in subsequent gatherings, and a little digging about the base of the stem showed that it originated in every case from a large, irregularly lobed, brown, firm, tuber-like body buried a few inches deep in the humus. This body, which was somewhat cartilaginous in consistency, showed, when cut, a chambered structure (*figs.* 5 and 6), the interior being traversed by light and dark more or less contrasting winding areas, closely resembling those characteristic of many Tuberaceae or Hymenogastreae; and at first sight it seemed not impossible that the Wynnea might actually be parasitic on some hypogaeous fungus. A microscopic examination of sections cut from this tuber, however, showed no signs of any structures which could by any possibility be considered to represent modified hymenia. The chambered interior, as is shown by the accompanying figures, is surrounded by an external layer or cortex of large, empty, thin-walled, brownish cells, those on the surface showing signs of degeneration

and wearing, which is rather abruptly succeeded by a peripheral region lying beneath it, composed of densely woven brownish filaments. As these filaments pass toward the interior, they become more loosely woven, the walls are much thickened, and the living protoplasmic contents are evident; the brownish tinge is lost as they pass into the white or colorless more or less gelatinous areas by which the adjacent chambers are separated. The chambers themselves show the greatest irregularity in contour, and are clearly marked off by a layer of dark cells which line them and contrast rather abruptly with the intermediate colorless areas above mentioned. These dark hymenium-like layers closely resemble the general external layer, and are made up of dark-walled, rounded, empty cells of somewhat smaller size, packed irregularly four or five deep; the somewhat ragged appearance of the superficial ones suggesting the lysigenous origin of the cavities which they line. Two such layers lying one on each side of an intermediate colorless region thus form the wall separating the cavities of two adjacent chambers (*fig. 6*). The early condition of this tuber-like body could not be determined, since all the specimens examined were well matured, and showed no signs of developing chambers. The body, however, appears to be in the nature of a sclerotium, which from its spongy structure may possibly serve the double purpose of supplying moisture as well as nutriment to the developing apothecia.

An examination of the specimens of *Wynnea gigantea* in the Curtis Herbarium shows that this species is characterized by a general habit closely resembling that of the Carolina form; and the main stem, where present in these specimens, is evidently broken from some attachment which may safely be assumed to have been a sclerotioid body similar to that above described. The presence of such a body might offer an additional reason for retaining BERKELEY'S genus, but its characters seem otherwise quite sufficient to remove it from Midotis or other known discomycetous genera. In regard to Midotis it may further be said that no one appears to have any definite knowledge of this genus at the present time, and it is altogether doubtful what the nature of this generic type really is. The name is first mentioned by FRIES (Syst. Orb. Veg. 363), without further allusion to a specific form than the remark "Species unica pleuropus;" while

in the *Elenchus* (**2**:29), published five years later (1830), the first mention of the type species, *Midotis lingua*, appears. This fungus, which is described as growing "ad basos truncorum" and as possessing an *inferior* hymenium, has not been found again, so far as is known; and it seems quite uncertain what it may have been, or even if it were anything more than some well-known form growing under abnormal conditions. The only discomycete known to the writer which might be referred to Midotis, and which possesses a truly inferior hymenium, is a plant found growing on dead logs in September, 1889, near New Haven, and again at Burbank; the material in the former locality being rather abundant. The apothecia are very thin, broadly spathulate, proliferous, and fasciculate, having a habit of growth very like that of some basidiomycete; the spores small and insignificant, and the inferior hymenium very characteristic and by no chance accidental. This plant, which has been provisionally referred to *M. plicata* Cke. & Hark., may perhaps really be a Midotis in the Friesian sense, on account of the unusual position of its hymenium; but that the other species included in the genus by various writers really belong here seems doubtful. The only species among these for the most part tropical forms, that the writer has examined, is the Cuban *M. verruculosa* B. & C., in which it is not possible to determine whether the hymenium is inferior or not. The status of Midotis itself being thus decidedly uncertain, it seems doubly undesirable to include in it the members of what at least appears to be a well-marked and peculiar genus.

Within the past year Mr. MASSEE has been so kind as to send to the writer a small fragment of the type material of *Wynnea macrotis* and *W. gigantea*, and, as has already been mentioned, he has examined the specimens of the latter species in the Curtis Herbarium, which form a part of the original gathering of BOTTERI, and include one large and very well-developed example. None of these, however, correspond very closely to the figures given by BERKELEY and COOKE, the apothecia, though somewhat more blunt than in the Carolina form, hardly presenting the thin, broadly spathulate, and freely proliferous habit represented in these drawings. Mr. MASSEE informs me that in his opinion the Berkeleyan species are not specifically distinct, although the color and habit of the two are so very differently represented in the *Micrographia*.

A comparative examination of the spores in all three species shows that when fully mature all are characterized by the presence of longitudinal markings, apparently corresponding to slight depressions and somewhat roughened intervening elevated regions which extend the whole length of the spores. Although these markings are conspicuous in the Carolina species, they are hardly visible until the numerous oily globules with which the spores are originally filled (*fig. 4*, upper spore) have been obliterated by treatment with glycerine or otherwise (*fig. 4*, two lower spores). While they are much less striking in *W. gigantea*, they are nevertheless readily seen (*fig. 8*), but in the material of *W. macrotis* received from Mr. MASSEE, they are exceedingly faint, possibly owing to the fact that the spores may not have been thoroughly matured. In all three species the spores are characteristically inequilateral, being more strongly curved on one side than on the other, apparent deviations from this rule being probably in all cases due to differences in the point of view. While in *W. macrotis* and *W. gigantea* they are bluntly rounded, they are more or less conspicuously apiculate or papillate at each extremity in the Carolina species, and the spore as a whole is distinctly larger. The spores of *W. macrotis* sent by Mr. MASSEE (*fig. 7*) are slightly smaller than those of *W. gigantea;* but the difference is insignificant, and could not serve to distinguish the species in the absence of other distinctive characters. Nevertheless it seems more desirable to retain both the Berkeleyan species until further data may be obtained by a re-examination of fresh material.

For convenience of reference the original descriptions of BERKELEY are quoted below. The genus may be characterized as follows, the sclerotium of the Carolina form being assumed to occur in the other species as well.

WYNNEA Berkeley & Curtis, Jour. Linn. Soc. **9**:124. 1866.

Apothecia thick, firm, subcartilaginous, tough and subcoriaceous on drying, erect, elongate, ear-shaped, simple or subproliferous, several- to many-clustered on a common stalk arising from a sclerotium buried in the substratum. Paraphyses cylindrical, simple or branched. Asci cylindrical, tapering to an elongated base penetrating the subhymenium with the filaments of which it is continuous, without articulation. Spores large, inequilateral.

WYNNEA GIGANTEA B. & C., Jour. Linn. Soc. **9**:124. *pl. 17. fig. 31. Midotis gigantea* Sacc. Sylloge **8**:547.

"Common stem three inches high, three-quarters of an inch thick, deeply rugose and cracked, so that the surface resembles that of Opegraphae; above divided repeatedly, with subdivisions elongated into ear-shaped cups, which are smooth externally, but wrinkled, though not cracked like the stem when dry; the cups are from two and one-half to three inches long, with incurved margins variously divided and sometimes proliferous. Asci cylindrical, containing eight subcymbiform spores .00095 inch long, and more or less obtuse at either end. When steeped in water, the inside of the stem acquires a slight foxy tinge. The substance is so totally different from Peziza, though this curious fungus is closely allied to *P. leporina* and *P. onotica*, that it cannot be placed in the same genus. *Peziza macrotis* Berk., a species found abundantly at Darjeeling at 7,500 feet, is clearly congeneric and may be characterized *Wynnea macrotis* Berk., etc."

Collected near Orizaba, Mexico, by BOTTERI, without note as to substratum.

WYNNEA MACROTIS Berk.

Peziza macrotis Berk., Hook. Jour. Bot. & Kew Gard. Misc. **3**:203. 1851. *Wynnea macrotis* Berk., Jour. Linn. Soc. **9**:124. 1866. *Midotis macrotis* Sacc., Sylloge **8**:547.

"Inodorous, dry, firm, leathery, subcartilaginous, varying in size, sometimes five inches long; erect, tufted, connate below and thence branched; cups elongated, oblique auriform, of a bright liver color, smooth externally; margin subinvolute. Hymenium even, purplish. Sporidia oblong-elliptic, with one side in general more convex. Nucleus single, in dried specimens."

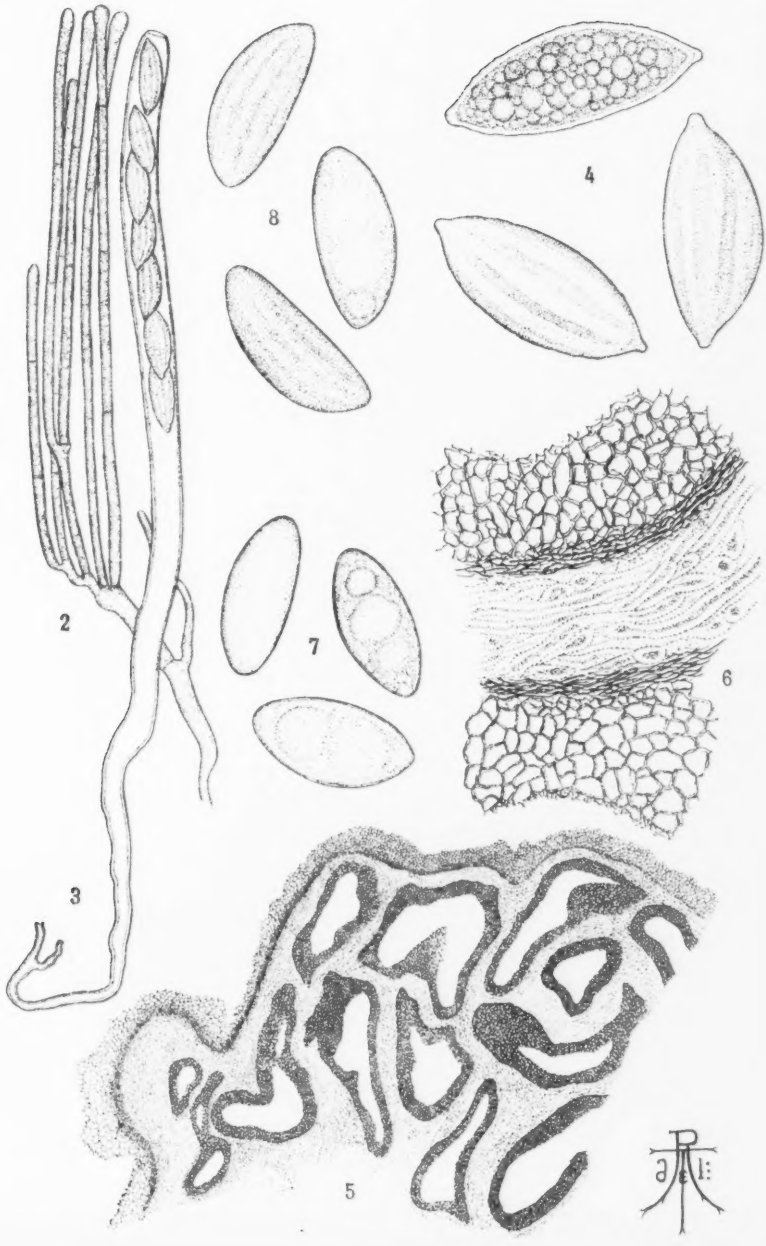
On rotten wood Darjeeling, India, 7500^{ft}, June-July.

Wynnea americana, nov. sp.

Sclerotium tough, subgelatinous, coriaceous on drying, irregularly lobed, variable in size, 50×40^{mm} more or less, brown. Main axis becoming variously divided above almost immediately after emerging from the ground, the short divisions giving rise at once to clusters of apothecia of variable size and number. Apothecia several to about twenty-five on a single plant, typically simple, rarely proliferous, erect, elongate ear-shaped, very variable in size; the longest seen 130×60^{mm}, the average about 80^{mm}, the margins somewhat

L. C. C. KRIEGER, PINX.

THAXTER on WYNNEA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involute on drying, the external surface rich blackish-brown, finely verruculose, the roughness due to projecting groups of irregular parenchyma-like cells becoming somewhat hair or chain-like toward the margins. Hymenium even, dark dull purplish-red, or brown. Asci elongate, about 500–540 μ long, the sporiferous part cylindrical, about 18 μ in diameter. Paraphyses septate, simple or irregularly branched, clavate, the slightly brownish terminal enlargement more abruptly and conspicuously distinguished in older specimens. Spores eight, subcymbiform, 32–40×15–16 μ, the extremities apiculate or papillate; marked when mature by about eight roughened areas running longitudinally and separated by a corresponding number of smooth slightly depressed areas, the spore when fresh completely filled by numerous small round refractive oily masses.

Growing on the ground in rich woods, Burbank, East Tennessee, and Cranberry, North Carolina.

Professor DURAND has kindly allowed me to examine a specimen collected by E. WILKINSON at Mansfield, Ohio, and communicated by Professor KELLERMAN, which corresponds in all respects with the Carolina plant. The spores of BERKELEY'S species differ in shape and in their smaller size; those of *W. gigantea* measuring 25–30×12 μ, and those of *W. macrotis* received from Mr. MASSEE 20–25×11–12 μ. The apothecia of *W. gigantea* seem also to be somewhat smaller, more rounded distally, more numerous in a single plant, and distinguished by their much paler color.

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EXPLANATION OF PLATES IV AND V.

FIGS. 1–6.—*Wynnea americana* Thaxter.

FIG. 1. General habit of a well-developed plant. For the original of this figure, done in color by Mr. KRIEGER from a formalin specimen and colored sketches of my own from fresh material, I am indebted to Professor FARLOW.

FIG. 2. Paraphyses.

FIG. 3. An ascus showing connection with subhymenial filament.

FIG. 4. Three spores, the upper in optical section.

FIG. 5. Portion of a section of the subterranean sclerotium showing chambers and cortex. Leitz obj. C+oc. 1.

FIG. 6. Portion of walls between two chambers. Leitz obj. 1+oc. 1.

FIG. 7. *W. macrotis* Berk. Three spores, two in optical section.

FIG. 8. *W. gigantea* Berk. & Curt. Three spores, one in optical section. The spores were drawn with Zeiss apochr. 1.25^{mm} and 4 ocular.

ON THE DEVELOPMENT OF HAMAMELIS VIRGINIANA.

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY OF JOHNS HOPKINS UNIVERSITY, No. 3.

D. N. SHOEMAKER.

(WITH PLATES VI AND VII)

INTRODUCTION.

THIS work on Hamamelis was undertaken on account of its peculiar habit of flowering. It is one of the few angiosperms that flowers in the fall and matures fruit the following year. This peculiarity made it seem worth while to investigate its entire embryological history, and especially the behavior of the pollen tube and the time and manner of fertilization. The subject was suggested by Dr. D. S. JOHNSON, to whom I wish to express my gratitude for sympathetic guidance and instruction during its prosecution.

The literature of the family is not extensive, and none of it has to do with the embryology of any of its forms. The most complete working out of the anatomy and affinities is by REINSCH (12). BAILLON (3) carefully described the organogeny of the flower in *Hamamelis virginiana* and *Fothergilla Gardeni*. VAN TIEGHEM (14) worked on the secretory canals of Liquidambar and Altingia. THOUVENIN (13) described the structure of the root, stem, and leaves of various members of the family. The account given by NIEDENZU in Engler and Prantl's *Natürlichen Pflanzenfamilien* is the most complete I have seen.

In some American oaks, which require two years to mature seed, it has been found that fertilization takes place about a year after pollination. The statement is made by GOEBEL (15, p. 392) that a period of rest occurs after the pollen tube has reached the embryo sac in Ulmus, Quercus, Fagus, Juglans, Citrus, Aesculus, Acer, Cornus, and Robinia. As Miss BENSON (4) points out, this statement is erroneous in the case of British Amentiferae. It is not true of Hamamelis.

In *Colchicum autumnale*, according to HOFMEISTER (7), the pollen

tube reaches the embryo sac at the latest by the beginning of November, and it is not until May of the next year that the embryo begins to form. This plant and the autumn-flowering species of Crocus, like *Hamamelis virginiana*, bloom and shed their pollen in the fall. HOFMEISTER'S account of Colchicum shows that it differs essentially from Hamamelis in the behavior of the pollen tube and the time of fertilization. The other genera named as having a longer or shorter period between pollination and the beginning of embryonic growth are all pollinated in the spring, so that the resting period for most of them does not extend through the winter.

The family of the Hamamelidaceae comprises some fifty species, in eighteen genera, of which eight are monotypic. North America has three representative genera: Hamamelis, Liquidambar, and Fothergilla. The first is found nearly always in such sheltered places as harbor *Polystichum acrostichoides*, from Labrador to Florida and west to the Mississippi River. The second is found on the coastal plain and on bottom lands from New York to Florida, thence to Central America, and up the Mississippi River to southern Indiana. The third is found from Virginia to Florida, east of the Appalachian Mountains. Hamamelis has two more species, one in southern China and one in Japan; Liquidambar is also represented by two species which occur in southern Asia from Asia Minor to Formosa; and Fothergilla is represented by one other species in Persia. The remaining genera are confined to southern and eastern Asia and Malaysia, with the exception of three genera found in Madagascar and southern Africa. Thus the whole family, with the exception of three genera, is confined to the eastern and southern parts of North America and Asia. This peculiar and as yet unexplained distribution occurs in a large number of genera, but this family is one of the most pronounced cases found. It should also be said that Hamamelites and Parrotia are found in the Dakota group of the Cretaceous (9), and that Hamamelis (5) and Hamamelidanthium are found in Eocene strata in northern Europe, so that the family had formerly a much more extended range than at present.

I have usually found Hamamelis on rather steep hillsides with a northern exposure, or more rarely on low ground along streams. It is said to grow abundantly on mountain tops in Pennsylvania

and western Maryland, and COWLES (6) reports it as growing on sand dunes near Chicago. From his description, however, it is doubtful if the seed had germinated in these dry localities. It has thus a very restricted range, and seems to grow only in positions in which moisture is abundant and transpiration slow. Liquidambar is confined to alluvial soils and moist situations, and so follows river valleys and coast lines; its northern limit is the valley of the Hudson River in New York. Fothergilla grows in moist places.

The material of *Hamamelis virginiana* and *Liquidambar* for the present work was obtained from the region about Baltimore, from northern Virginia, from Long Island, and from southwestern Ohio. I am indebted for exotic forms to the kindness of Mr. GEO. V. NASH, of the New York Botanical Gardens, and to Mr. J. G. JACK of the Arnold Arboretum, Jamaica Plain, Mass. The long period of development made it necessary to collect nearly every week of the year for Hamamelis. Material of Fothergilla was collected in central South Carolina.

Killing and fixing was mostly done with a sublimate-acetic mixture made by adding 5 per cent. glacial acetic acid to a saturated aqueous solution of corrosive sublimate; this was often used hot. The material was cleared in xylol and imbedded in paraffin; and sections were cut 5 to 15 μ in thickness. For staining, a combination of haem-alum and Bismarck brown was tried, but Flemming's triple stain was found more satisfactory and was used almost exclusively. It was necessary before the young carpels could be sectioned in paraffin to remove carefully and laboriously the hairs from their bases, as on account of their thick walls the hairs could not be cut in paraffin, invariably tearing the sections. To avoid this process celloidin imbedding was used in a few instances, but it was impossible to get the sections thin enough for most purposes.

ORGANOGENY OF THE FLOWER.

The flower buds arise from axils of the leaves of the current year, or from latent buds of the two preceding years, and appear early in May. They, as well as the leaf buds and the young twigs, are covered by a dense coating of tufted hairs. Each hair develops from a single epidermal cell, which protrudes from the surface and is cut by anti-

clinal walls into four to twenty cells, each of which sends out a long process, making a many-rayed star. They are often raised on a low multicellular papilla.

Each flower bud produces a head of two to four flowers, and there are often as many as three buds from an axil. At first the tip of each bud is protected by three or four alternate bracts, which are soon left below on the stem of the flower head and finally fall off. The first floral organ to appear is the outside bract of each flower. As the buds grow the other two bracts arise successively, one on each side of the flower. The sepals appear in pairs, the first pair being anterior and posterior. The petals then arise in one cycle of four rudiments, inside which two successive alternating cycles of four rudiments each develop. The outer cycle, opposite to the lobes of the calyx, becomes stamens, the inner sterile staminodes.

The torus by this time, through unequal growth, has become concave, and on its floor are developed two horseshoe-shaped ridges, one anterior and one posterior. These grow together on the median line, and this line of fusion is carried upward by growth, so that there is a solid wall between the cavities of the carpels for a short distance. The carpels have separate styles and stigmas, but are united throughout their hollow portions. In each ovary there is found one ovule, which is suspended from the margin of the carpel. This development of the flower is essentially as described by BAILLON (3), except that he describes the ovary as originally having two ovules, one of which nearly always atrophies. LE MAOUT and DECAISNE (16) also figure a cross-section of the fruit showing two mature seeds in each carpel. Although I have examined several hundred carpels I have found but a single one with two ovules. BAILLON (17) also speaks of Hamamelis as being polygamous, but of this I have seen no evidence in my material. It is possible that these conditions may occur more frequently in places from which I have no material, or in other surroundings, yet the form has been very constant from all my collecting points.

In the mature flower the temporary parts, the stamens, petals, and nectaries, are smooth. The outside of the sepals and bracts, and the bases of the carpels are thickly covered with hairs. *Figs. 8* and *9* show how the rudiments of the growing flower fit together, and

how the bud is protected by its hairy covering. Most of these hairs have a double function. While young they act as slime cells in keeping the growing point and growing tissues moist, this function being best performed by the hairs on the tips of the sepals and bracts, and the bases of the carpels. These young hairs are long and tortuous, and wind among the growing rudiments (*fig. 9*). Their cavities are full of sap, and their nuclei take a very dark stain; they remain in this active stage longer than hairs on other parts of the plant. As they grow older all the hairs acquire thick cell walls, and tend to straighten. In their mature state they act as a protection against moisture. This function they perform by means of a waxy covering which repels water, so that it is very difficult to moisten a young flower bud, or a growing twig, or fruit; but if these hair-covered parts be soaked a short time in strong alcohol, and allowed to become dry again, they may be very readily moistened.

POLLEN SACS AND POLLEN.

Each fertile stamen rudiment begins early to form two microsporangia. There is apparently no evidence of the presence, at any stage, of the other two microsporangia that are usually found in angiosperms. No indication of pollen-formation is ever seen in the sterile rudiments.

The first evidence of the formation of the archesporium is found about the middle of June. The subepidermal layer divides by periclinal walls at the place where the microsporangia are to be formed (*fig. 1*). The exact derivation of layers is hard to trace, but it is quite certain that it is from the inner layer thus formed that all the archesporial tissue comes. By the middle of July the archesporium is well blocked out, and shortly after the spore mother-cells are formed. At this stage there is about them a moderately well-defined tapetum, and the outside wall of the microsporangium is three or four cell layers in thickness (*fig. 2*). Here the pollen mother-cells are only noticeable by their slightly larger nuclei and more deeply staining contents.

The further growth of the microsporangium is brought about by the increase in size of its cells, both sporogenous and tapetal. Before the tetrad division, the nuclei of the tapetum divide without

the formation of cell walls, and the tapetal cells have two or three nuclei each; the nucleoli also increase notably, and the contents of the cell become more largely vacuolate (*fig. 3*). The pollen mother-cells thicken their walls, and soon float freely in the cavity of the anther; increasing further in size, with a much larger nucleus and nucleolus (*fig. 29*). The two tetrad divisions occur almost simultaneously, although stages are found showing two nuclei (*fig. 30*). In the tetrad division the nuclear processes do not show at all clearly, though there seem to be fibers connecting the nuclei in one stage observed (*fig. 31*). The pollen grains have cell walls and but one nucleus when the mother-cell wall is broken down (*fig. 32*) and the grains released into the cavity of the microsporangium. The mature grain was described by VON MOHL, very briefly, in 1835. It has the shape of an oblate spheroid, with three meridional furrows (*fig. 33*); between these furrows the surface is covered by a fine reticulation. An equatorial section shows that the intine is strongly developed under the furrows, which gives the section of the interior a decidedly three-lobed appearance (*figs. 33* and *34*).

Soon after the pollen grain is freed from the mother-cell, its nucleus divides, and the smaller nucleus, probably the generative, retires into the extremity of one of the lobes. Here it becomes closely applied to the intine and is cut off from the larger cell by a very noticeable wall, which is probably of cellulose (*fig. 33*). Shortly before the pollen is shed this wall disappears, and the two nuclei then lie free in the cavity of the grain. The larger of the two, the tube nucleus, is loosely vesicular, while the structure of the generative nucleus is dense and deeply staining (*fig. 34*).

Of the four layers in the microsporangium wall only the subepidermal layer has any part in the opening of the anther, becoming the fibrous layer and covering the inner and lateral faces of the anther (*figs. 5* and *6*). The first and for a long time the only evidence of the differentiation of this layer is the radial lengthening of the cells. At this stage it is possibly not inappropriate to mention an instance of regeneration observed in this fibrous layer. From some unknown cause, the first subepidermal layer had been destroyed over a small area. The remaining part of that layer had developed normally. Into this gap tissue had grown from both sides, but that which came

from below was slight in amount, and had retained its original character; while the epidermal cells had greatly elongated and had divided into epidermal and secondary fibrous layer cells (*fig. 4*). These secondary fibrous layer cells resembled very closely at this stage those of the primary fibrous layer, and I see no reason to suppose that they would not have developed fibers at the proper time. Here then the epidermis seems to have been more plastic under the injured spot than the deeper lying tissues.

The fibers are developed in this layer shortly before the time the anther is to open, appearing on the side and bottom of each cell. Around the top, posterior, and bottom of the microsporangium there is a groove (*figs. 5* and *7*), and in the bottom of it the cells have no fibers and are quite thin-walled, so that they readily break, thus forming the line of dehiscence of the anther. As LECLERC DU SABLON (8) has shown for anthers in general, the opening is due to unequal shrinkage of the two walls of the fibrous layer. The outer wall being of cellulose, shrinks more on drying than the inner wall, which is strengthened by its lignified fibers. By this means the whole outer covering is bent upon itself and points directly toward the carpels (*fig. 7*); nearly all of the pollen adheres to these wings, and so is placed in the way of any insect that comes to visit the nectaries. The stigmas are ripe for pollination at the same time that the anthers open. Any insect visiting many flowers in succession must scatter pollen promiscuously, so that there is sufficient adaptation to insure cross-pollination, but no well-developed mechanism to prevent self-pollination. Pollen is ripe and begins to be shed in the latter part of October, and is shed from that time on into the winter, as the flowers keep opening with each return of warm weather, even as late as January.

OVULES AND EMBRYO SAC.

The ovules show specialization of archesporial tissue at the tip of the nucellus before the integuments have begun to develop, but it is very difficult to distinguish archesporial cells, although there seem to be several of these, each one cutting off a tapetal cell which divides repeatedly. The cells of this tissue then elongate in the direction of the long axis of the nucellus, and bury the mother-cells by some eight layers of cells in the nucellus.

It is also probable that this part of the nucellus forms the extremity of the conducting tissue for the pollen tube. In early stages three to five macrospores can be seen, but only one germinates. This goes through the usual stages, the resulting nuclei being arranged in the order most often found among angiosperms (*fig. 10*). The antipodals very early disappear, so that they are hard to find at the time of fertilization. The endosperm nucleus is found about the middle of the sac.

The tissue surrounding the mature embryo sac is much disintegrated (*fig. 10*). Around the chalazal end of the sac the tissue always stains deeply, and there is a quite evident strand of conductive tissue from the tip of the fibrovascular bundle at the chalaza to the lower end of the embryo sac (*fig. 10*). The base of the nucellus shows by its smaller cells that it is the most rapidly growing part. The development which the ovule has attained at the beginning of winter is shown in *fig. 11*. The integuments up to the early part of April are still behind the nucellus in growth; in spring their growth is hastened and they soon project beyond the nucellus, leaving a wide open micropyle (*fig. 21*). This is finally closed to a slit-like fissure between the edges of the outer integument.

The outer integument is now quite thick, formed of about eight layers of cells, and is uniform in structure throughout. The inner integument is made up of three layers of cells which are very much alike. The epidermal layer of the nucellus has already become slightly different from the underlying tissue.

POLLEN TUBES ARTIFICIALLY GROWN.

Pollen taken from open anthers was very readily sprouted in a 16 per cent. sugar solution made with tap water, in which 1.5 per cent. gelatin was dissolved. The pollen grains first became spherical by the filling out of the furrows, thus using the masses of intine on the inner sides of the furrows. Tubes sprout from the pollen grains when placed in the nutrient gelatin in one to three hours, and always arise from the smooth bands. The cultures were kept at room temperature and growth was more luxuriant in the dark. The growth of molds, etc., usually disturbed the cultures at the end of a few days.

The behavior of the nuclei was not readily observed. Methyl-green-acetic-acid was used to kill the pollen tubes, and no more

than two nuclei were ever found in a tube. The tubes showed a marked tendency toward the formation of cellulose plugs (*fig. 12*). It rarely occurred that part of the contents of the tube was in this way shut off, as the spaces walled off by plugs were mostly empty.

In the course of about three days' growth the pollen tube frequently "encysted" (*fig. 35*), that is a spherical swelling developed at the tip or near the tip of the tube into which nearly all the contents of the tube were withdrawn, including one or both nuclei. A wall was then formed completely closing off the swelling, which was often as large as the original grain. I have not determined the exact conditions which called forth this action, neither have I found such things in the style in normally grown pollen tubes. Miss BENSON (4) reports a case of somewhat similar character as occurring in Carpinus, though the spherical character and the separating wall were not nearly so pronounced. She suggests that this may be of use in the short resting period of this form, but was not able to find such appearances in the style.

The pollen showed ability to sprout at room temperature whenever the flowers opened. A collection made in Ohio early in January, after the unopened buds had endured a week of very cold weather, when the temperature had been as cold as $-15°$ F., sprouted in a seemingly normal way, though not so vigorously as earlier. I am inclined to think, however, that pollen shed so late never functions.

CONDUCTIVE TISSUE OF THE STYLE AND OVARY.

By the folding of the carpels each style has a groove formed, which leads from the stigma to the ovary. It is open at the top, and where its sides are slightly separated and its inner surface thus exposed, it bears the loosely arranged papillose cells of the stigma. The epidermis of the groove and two subepidermal layers continue this stigmatic tissue down to the base of the funiculus, the strand of conducting cells getting gradually deeper and deeper in the tissue of the style. The cell walls of the strand are thickened, partly gelatinized, and the contents of the cells are dense. *Fig. 13* shows its appearance and position about midway in the height of the style, and its course in longitudinal section is shown in *fig. 18*. When the flower first opens, the epidermis of the funiculus is not yet differentiated,

but as winter approaches the base of the funiculus becomes glandular. The epidermal cells enlarge, the walls thicken, and the contents become vacuolated. In the spring this process is carried still farther, and as the ovule occupies more and more of the cavity of the ovary, these cells secrete a mucus which fills the small remaining cavity around the base of the funiculus (*fig. 10*).

THE DESCENT OF THE POLLEN TUBE.

The pollen grains begin growth very shortly after falling on the stigma, and the growth is at first comparatively rapid. Its course is readily traced in the conducting tissue of the style, which is greatly disorganized by the growth of the large number of tubes usually present. The course is between the cells rather than through them. By the time that winter sets in the living part of one or more tubes is to be found in the neighborhood of the base of the funiculus (*fig. 11*). There are usually several living tubes at varying heights in the style at this time (*figs. 17* and *18*), and evidence of many more which have been stranded above. The unprotected tip of the style is dead and withered, while that part which is clothed with hairs is alive. It is in this protected part of the carpels that the pollen tubes hibernate. Soon after pollination the flower head twists on its stalk so as to invert the blossoms. The inverted calyx then very effectually protects the carpels from rain, sleet, and snow.

The pollen tubes found at this time are usually of greater diameter than at the beginning of growth. Tubes grown in sugar-gelatin solutions are 5 to 8 μ in diameter, and those which sprout on the stigma are at first about the same size; but those found during the resting stage are 12 to 15 μ in cross-section, and the wall is thicker than at first (*fig. 14*). The nuclei found did not exceed two in any tube.

When growth is renewed in the spring, the area of conducting tissue in the funiculus being increased, the pollen tube is soon seen in the cavity of the ovary. More than one tube may reach the ovary. At first the ovule is by no means ready for fertilization, and the integuments have not yet closed up the micropyle (*fig. 21*). The tubes do not appear at this time to have any definite direction of growth, but grow down beside the ovule or into the wide open

micropyle, or between the integuments. The course to the egg cell is through the micropyle and into the tip of the nucellus through the tissue derived from the tapetal cells, which stains deeply at the time and is probably conductive tissue. Thus it is seen that the tube grows just about as fast as the conductive tissue is prepared for it, and stops in the fall when it reaches the end of the mature conductive strand. The transference of the male nucleus has not been observed, but fertilization takes place about the middle of May, which is from five to seven months after pollination.

ENDOSPERM.

The antipodals very early disappear. The first result of fertilization is apparent in the action of the endosperm nucleus, which immediately begins to divide. The stage of free endosperm nuclei is very short, as cell walls have appeared in the twelve-nucleate stage. These walls first arise in the bottom of the embryo sac. Both endosperm and nucellus grow rapidly from this time forward. The endosperm early disintegrates the neighboring nucellar tissue except at two points, the tapetal strand of tissue leading down from the micropyle and bearing the fertilized egg at its lower end, and the pit at the chalazal end of the embryo sac which earlier held the antipodals. This and the deeply staining tissue surrounding it resist the action of the endosperm for some time, and by the growth of the base of the nucellus are pushed into a position on the side of the growing endosperm (*fig. 23*). This antipodal pit is finally absorbed.

The nucellus keeps pace with the growing endosperm, its epidermal layer being changed to make part of the inner seed coat. The differentiation of this layer is shown mainly by the larger size of its cells, especially at the tip of the nucellus, and by the crowded cell contents which take up blue stains very readily. This layer is the only part of the nucellus that permanently resists the action of the endosperm, and it is completed across the region of the chalaza so that it entirely surrounds the endosperm. Its nuclei are usually applied to the outer cell wall, and help doubtless in making the clear membrane which surrounds the nucellus in the mature seed. It is thrown into folds shortly before the ripening of the seed (*fig. 20*). The endosperm

is finally stored with food in the form of proteid grains, which shortly before ripening show numerous globoids (*fig. 22*) that disappear later. The ripe endosperm contains in its cells much oil along with proteid material, and in the cell walls there are imbedded numerous crystals of calcium oxalate (*fig. 15*).

THE EMBRYO.

The embryo begins growth comparatively late, so that the endosperm has already acquired some size before the first division of the egg occurs. The egg after fertilization becomes slightly imbedded in the tissue of the tapetal strand, and enlarges greatly. The first division is transverse and cuts off a small cell below and a large one above. By this continued cross division the suspensor may have five or six cells (*fig. 23*). The first division of the embryo is longitudinal. The embryo dissolves the endosperm in much the same way as the endosperm dissolves the nucellus, and lies free in a cavity formed by the disintegration of the endosperm. At maturity there is a straight axial embryo which extends from end to end of the seed and is richly stored with oil and proteid material in all its cells. The upper side of the cotyledons has already a well-developed palisade layer (*fig. 24*).

INTEGUMENTS.

The inner integument is at the beginning three cell layers in thickness, the innermost layer taking part in the formation of the inner seed coat. It early becomes filled with dense contents that stain blue readily (*fig. 20*), and finally shrink and become applied to the inner cell wall. The remaining layers are crumpled up so that they can only be made out with difficulty.

The outer integument thickens greatly, and its cells elongate, taking a curved oblong shape. The cell walls then begin to thicken and the whole integument forms the outer seed coat which is moderately hard, black, and very resistant to water. The outer integument is very smooth over the whole surface, except at the place of attachment of the funiculus, where there is a white saddle-shaped scar. The seed is ovoid, but very decidedly pointed at the lower end. The shape of the seed is a very important part of the discharging mechanism.

THE CARPELS.

At blooming time the carpels are very slightly imbedded in the tissue of the torus (*fig. 17*). There is a very short calyx tube, however, shown in the figure below the attachment of the anther. As the fruit matures, the calyx tube lengthens proportionately more than the carpels, and this gives the fruit the appearance of being half buried in the torus (*fig. 38*). A longitudinal section (*fig. 39*) shows that this is only apparent and that the fruit is only slightly buried.

The substance of the carpels develops into two tissues, the outer one becoming fleshy with numerous roundish stone cells, the inner one forming part of the mechanism for expelling the seed. In each carpel this inner layer is formed in two halves, which are not closed at the top and are higher toward the posterior of each carpel, as shown in side view in *fig. 42*. These halves are never closely joined on the inner sides of the carpels, and there is provision for a split along the dorsal line also. The cells are developed into fibers diagonally from the inner edge to the dorsal line of each carpel, parallel to the top of the layer. In opening, this layer splits down the midrib of the carpel and in front. It then opens at the top and each half below begins to contract in a transverse direction. The cross-section of the opening layer is shown before contraction in *fig. 40*, after the opening of the fruit in *fig. 41*. The pressure exerted comes gradually on the seed, and it is thrown out, not by a sudden movement of the capsule, as in many such contrivances, but by being pinched on the smooth pointed lower end. The great smoothness of the seed and of the inside of the capsule assists greatly in the process. The seeds are often thrown to a distance of twenty feet. This movement is caused by drying, as can be proved by placing an opened capsule in water, when after some hours it will close entirely, and will open again on being dried.

GERMINATION.

The seed thus distributed lies on the ground for two winters according to BAILEY (1), sprouting the second year. Under trees which fruited abundantly in the fall of 1901, but where the crop was a failure in 1900, it was not possible to find young seedlings in May 1902, though many seeds were found. Under trees which fruited

in 1900 it was easy to get young seedlings in various stages. The cotyledons remain in the seed coats until they have absorbed the stored up nourishment of the endosperm (*fig. 16*); they are then freed and exposed as green assimilative leaves. Attempts at sprouting the seed in damp sphagnum were made in the laboratory. The seed was planted in September of 1900, and by May of 1902 had just begun to protrude the tips of the radicles. They had been in the temperature of an unheated room constantly, but had not been subject to frost, and had never been allowed to dry out.

HAMAMELIS ARBOREA.

I procured one stage of the Japanese species *H. arborea* in the latter end of October. This differs from *H. virginiana* in its time of flowering, which is in very early spring. A variety, *H. arborea zuccariniana*, flowers as early as February, and thus approaches the flowering time of the American species. The flowers are in about the same condition in October as those of *H. virginiana*, except that the stamens are rather backward. The pollen grains are free and have each two free nuclei, and evidently pass the winter in that stage (*fig. 36*). As the pollen is shed in March at the latest, it probably must rest about two months before fertilization occurs. The petals are coiled involutely in the bud as in *H. virginiana*, but instead of being entirely smooth have a tuft of hairs on the tips. In other respects the two genera are much alike in their development so far as studied.

FOTHERGILLA GARDENI.

An incomplete series of stages of this species was studied. Its flowers appear in the spring along with the leaves. It lacks a corolla, and its calyx tube is much longer than that of Hamamelis, having five to seven very small teeth. The development of the stamens is described by BAILLON (3). They arise first as five single rudiments, which are followed by other rudiments on each side, so that there are finally five groups of five or six stamens, those of each group being of different ages and different heights. They pass the winter in the pollen mother-cell stage. At the time of flowering the ovules are not yet ready for fertilization, so that the pollen must have a resting period of nearly a week. The anthers have four microsporangia and

open by two valves instead of one, very much as is common in most angiosperm stamens which open by slits. The structure of the seed and fruit is like that of Hamamelis, except that the seed is smaller.

CORYLOPSIS PAUCIFLORA.

Only one stage of this species was examined. It was obtained in the spring before the flowers open,which occurs before the leaves appear. They are borne in drooping racemes, with many bracts, which are smooth outside, but covered by silky hairs within. The structure of these hairs is much like that in Hamamelis, but they are not rigid. The stamens, which have four microsporangia, pass the winter containing nearly mature pollen grains (*fig. 37*), with two free nuclei. The ovule passes the winter in the same stage as does that of Hamamelis (*fig. 25*). It is difficult to determine whether there is present a definitive macrospore or a macrospore mother-cell; however, there is no evidence of the presence of more than one macrospore mother-cell. There must also be some time here between pollination and fertilization.

LIQUIDAMBAR STYRACIFLUA.

Liquidambar is not so closely related to Hamamelis as the other genera studied. The buds in this species pass the winter with the merest rudiments of the floral organs present. The stamens are only small protuberances which do not show any archesporium. The mature anthers have four microsporangia and open by slits (*fig. 26*). The fibrous layer is very slightly developed as compared with Hamamelis. The flowers are imperfect, with rudiments of stamens appearing as nectaries among the flowers in the female heads. These were formerly thought to be both petals and stamens; abortive pollen is sometimes developed in them, which is evidence of their staminal nature (*fig. 27*). The carpels, which occur in pairs as in Hamamelis, are collected into large heads containing thirty-five to fifty flowers each. Each carpel has a double row of ovules developed on marginal placentae, and a broadly expanded stigmatic surface. With very rare exceptions, only one of these many ovules is fertilized, and this one is near or at the bottom of the cavity. There is a week or ten days between pollination and fertilization in this case. The developing seed shows the same resistant tissue at the antipodal

end of the embryo sac as is found in Hamamelis, but here it persists into the ripe seed. The epidermal layer of the integument is not used up, and around the chalaza there is a small fragment of the nucellus left in the ripe seed. This is never stored with food materials, and so cannot be called perisperm (*fig. 28*). The macrospore is buried about as deeply as in Hamamelis. It germinates only in the lower ovules, the upper ones never showing typical embryo sacs and being less developed progressively toward the top of the ovary. In the sterile ovules the cells of the outer integument become very much enlarged and at last empty. The substance of the nucellus is absorbed, and the ovules become polygonal bodies, resembling sawdust, which fill the upper part of the ovary. The outer integument of the fertile ovule (*fig. 28*) grows into a wing. The embryo is straight, and in bulk bears about the same relation to the endosperm as in Hamamelis.

SUMMARY AND CONCLUSION.

1. In Hamamelis the anthers have two microsporangia from the beginning.

2. The generative cell in the pollen grain has a cell wall developed which is afterward dissolved.

3. The pollen tube when grown artificially shows a marked tendency to form cellulose plugs, and also forms spheres into which the contents of the tube are withdrawn. Thus far these phenomena have not been observed in normal growth.

4. The development of the pollen tube in the style may be divided into three periods: first period of growth, hibernation, and second period of growth. During hibernation the walls are thickened and the diameter of the tube enlarged, in the next stage having a smaller size and thinner walls.

5. There are several macrospores developed, only one of which becomes functional. It is deeply buried in the nucellus by the growth of tapetal tissue.

6. The germinating macrospore is nourished through a strand of conductive tissue from the chalaza.

7. The antipodals are sunk in the tapering lower end of the embryo sac. This tip is surrounded by deeply staining tissue which for a time resists the dissolving action of the endosperm.

8. The epidermis of the nucellus is the only part not used up by the endosperm. Its walls are thickened and it helps to form the inner seed coat.

9. Fertilization takes place in May, five to seven months after pollination.

10. The embryo is slow to begin growth and has a short suspensor.

11. The seeds sprout normally after lying on the ground for two winters.

12. The hairs serve a twofold function while young, to keep the growing tissues moist, and when mature to keep off moisture.

13. One case of the regeneration of the fibrous layer of the anther wall by the epidermal layer was observed.

14. The other investigated genera of the family all have a resting stage of the pollen, although it is much shorter.

15. The other genera of the family all have anthers with four microsporangia.

In comparing *Hamamelis virginiana* with its relatives, it seems certain that i. was once a spring-flowering plant, whose blossoming has worked backward through the winter. It differs from *H. arborea* essentially in the way its pollen passes the winter, for the development of each is much the same in October.

Most of the plants showing long resting periods in pollen growth belong low in the system, in the Amentiferae; but with the exception of some oaks Hamamelis has the longest resting period known. It seems probable, therefore, that this resting period can not be regarded as a primitive character in any case.

U. S. BUREAU OF PLANT INDUSTRY,
Waco, Texas.

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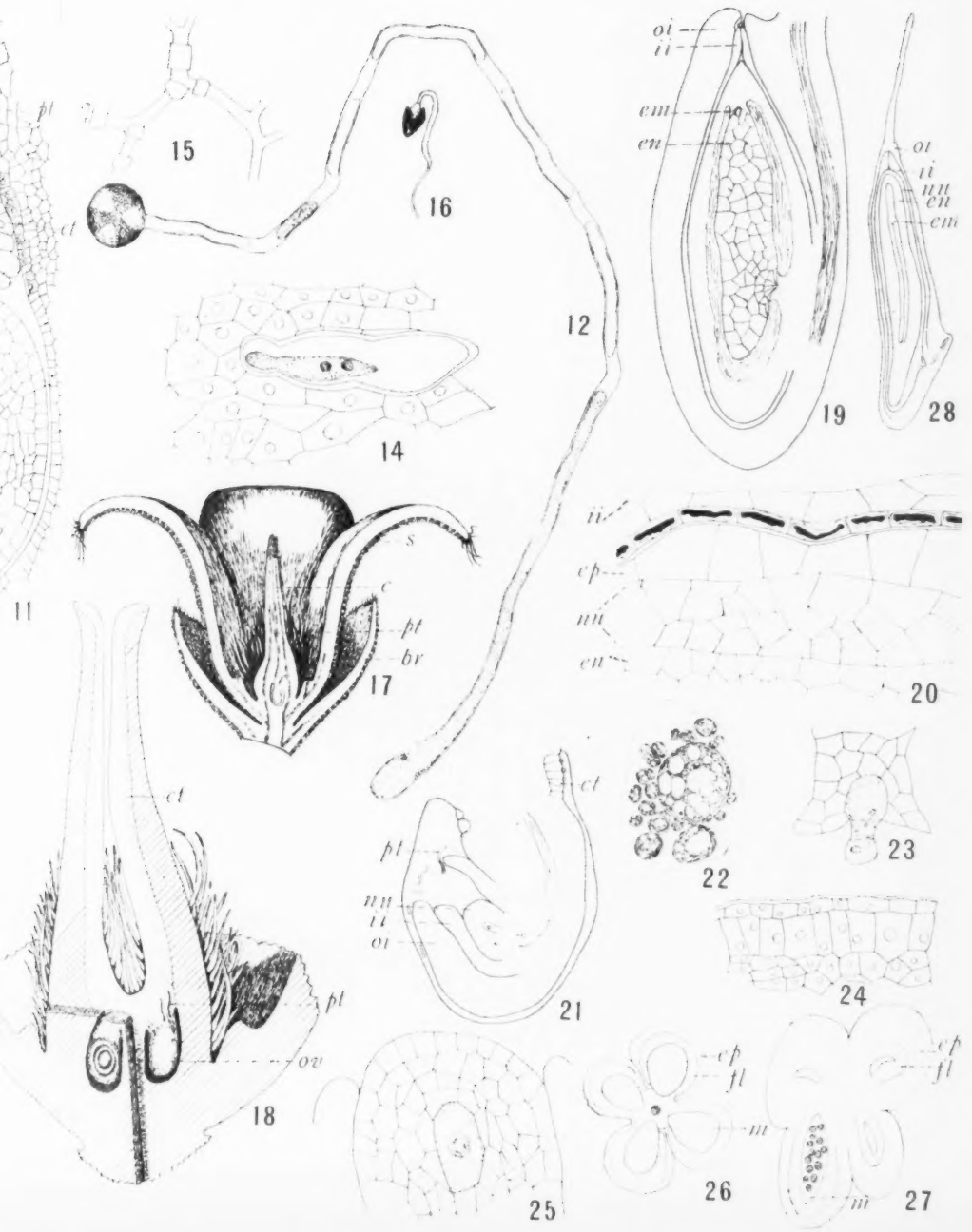
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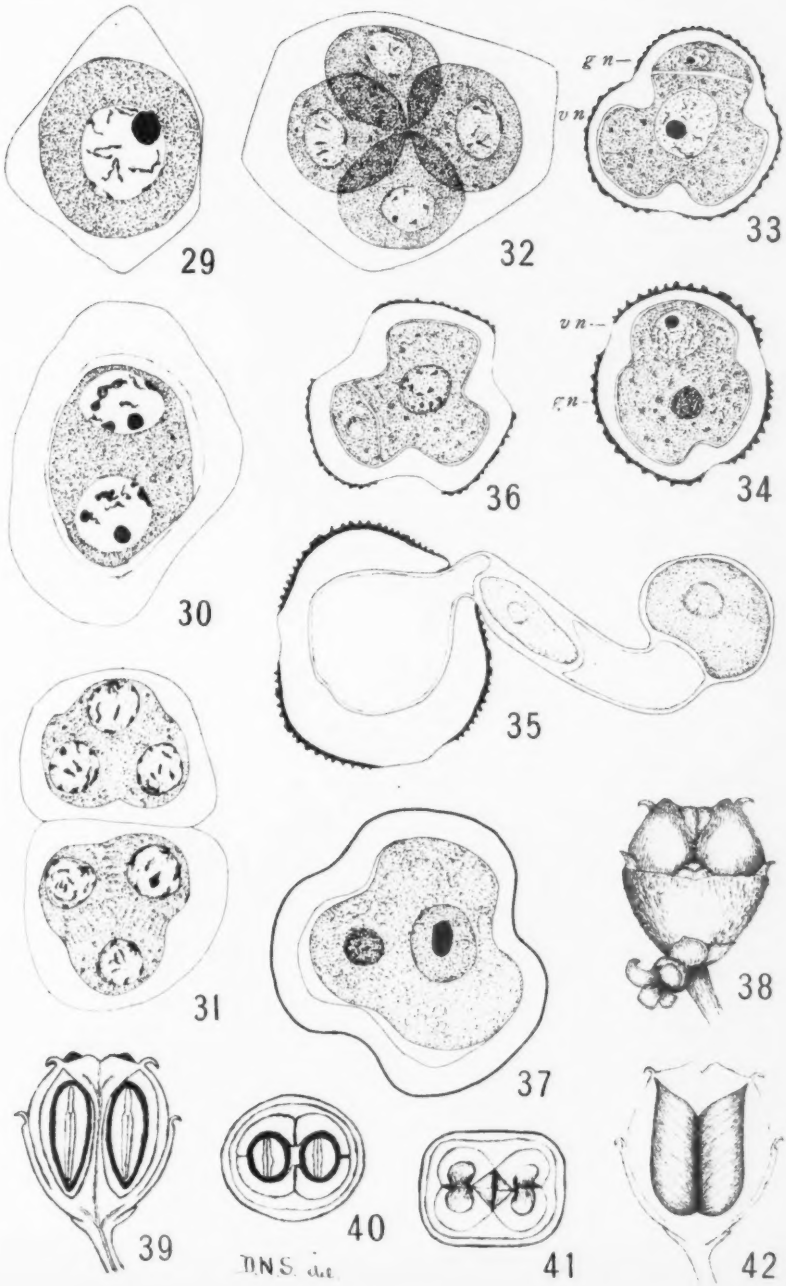
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EXPLANATION OF PLATES VI AND VII.

All figures were drawn with a Zeiss camera lucida, and are of *Hamamelis virginiana* unless otherwise stated. The magnifications indicated are those of the reduced plates; those of *Plate VI* having been reduced one-half, and those of *Plate VII* one-fifth. The abbreviations are as follows. *ar*, archesporium; *br*^{1}, *br*^{2}, *br*^{3}, first, second, and third bracts; *c*, carpels; *ccs*, chalazal conducting strand; *ct*, conductive tissue; *em*, embryo; *en*, endosperm; *ep*, epidermis; *es*, embryo sac; *f*, funiculus; *fl*, fibrous layer; *gn*, generative nucleus; *ii*, inner integument; *m*, microsporangium; *n*, nectaries; *nu*, nucellus; *oi*, outer integument; *ov*, ovules; *p*, petals; *pm*, pollen mother-cells; *pt*, pollen tube; *s*, sepals; *st*, stamens; *t*, tapetum; *vb*, vascular bundle; *vn*, vegetative nucleus.

FIG. 1. Growing stamen; longitudinal section. × 550.
FIG. 2. Growing stamen; transverse section. × 550
FIG. 3. Tapetum and pollen mother-cells. × 550.
FIG. 4. Anther wall showing regeneration. × 220.
FIG. 5. Mature anther; diagrammatic transverse section. × 35.
FIG. 6. Mature anther; diagrammatic longitudinal section. × 35.
FIG. 7. Mature anther, open; diagrammatic transverse section. × 35.

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FIG. 8. Growing flower bud; transverse section in plane *ab* in *fig. 9*. × 22.

FIG. 9. Growing flower bud; longitudinal section along line *xy* in *fig. 8*. × 22.

FIG. 10. Ovule; longitudinal section. × 97.

FIG. 11. Ovule at beginning of winter. × 220.

FIG. 12. Pollen tube with cellulose plugs, grown in gelatin. × 330.

FIG. 13. Style; transverse section. × 220.

FIG. 14. Hibernating pollen tube. × 550.

FIG. 15. Endosperm cell walls with crystals. × 550.

FIG. 16. Seedling in seed coats. × 1.

FIG. 17. Flower in winter; longitudinal section. × 9.

FIG. 18. Carpels in winter; diagrammatic longitudinal section. × 20.

FIG. 19. Ovule; longitudinal sections. × 35.

FIG. 20. Seed coats. × 175.

FIG. 21. Ovule in spring; longitudinal section. × 80.

FIG. 22. Endosperm cell stored with food. × 550.

FIG. 23. Embryo and suspensor. × 550.

FIG. 24. Cotyledon in seed. × 220.

FIG. 25. Nucellus of *Corylopsis pauciflora* in spring. × 550.

FIG. 26. Mature anther of *Liquidambar styraciflua;* transverse section. × 35.

FIG. 27. Nectary of the same; transverse section. × 35.

FIG. 28. Seed of the same, nearly mature. × 5.

FIG. 29. Pollen mother-cell. × 1745.

FIG. 30. First division of pollen mother-cell. × 1745.

FIG. 31. Second division of pollen mother-cells. × 1745.

FIG. 32. Pollen grain, in pollen mother-cell. × 1745.

FIG. 33. Pollen grain. × 1745.

FIG. 34. Pollen grain. × 1745.

FIG. 35. Pollen grain sprouted in gelatin. × 1745.

FIG. 36. Pollen grain, winter condition; *Hamamelis arborea*. × 1745.

FIG. 37. Pollen grain, winter condition; *Corylopsis pauciflora*. × 1745.

FIG. 38. Ripe fruit. × 1.6.

FIG. 39. Fruit; longitudinal section. × 1.6.

FIG. 40. Fruit; transverse section. × 1.6.

FIG. 41. Fruit, after discharge of seed; transverse section. × 1.6.

FIG. 42. Opening layer of capsule; side view. × 1.6.

SEXUAL REPRODUCTION IN THE RUSTS.

A. H. CHRISTMAN.

(WITH PLATE VIII)

THE nature of the aecidium has remained one of the most vexed questions in mycology. BLACKMAN'S[1] recent discovery goes far toward clearing up the most important points and my own results, described below, confirm his general conclusions, though showing a widely different method of conjugation. The literature relating to sexuality and the general cell processes in the rusts has been so thoroughly and justly reviewed and critically estimated by BLACKMAN that I need hardly devote further space to it here.

My studies on the winter conditions of the rusts and the nature of the aecidium led me to the preparation of material for cytological study, and in the spring of 1904 Professor J. C. ARTHUR proposed to Professor HARPER to furnish material from his cultures for cytological investigation. This material was turned over to me. It consisted of a quantity of carefully identified aecidia of several rusts, and since our knowledge of the method of origin of the binucleated condition found in the aecidiospores was at that time entirely lacking as to the details of the behavior of both cells and nuclei, my study was directed largely toward that point.

It was soon found that aecidia of the caeoma type, with unlimited growth, were by far the most favorable material. This type of development apparently admits of less crowding of the hyphae, and as a result the cells and their relations can be made out more easily. Two forms were further found especially favorable because of the large size of their cells and nuclei. These were *Caeoma nitens* S. growing on *Rubus* cult., and *Phragmidium speciosum* Fr. on *Rosa humilis*.

The best fixation was secured by the use of Flemming's fixing solutions; both the strong and weak were very satisfactory. Fixing solutions were sent to Professor ARTHUR and the specimens were

[1] BLACKMAN, V. H., On the fertilization, alternation of generations, and general cytology of the Uredineae. Annals of Botany **18**:323–373. *pls. 21–24.* 1904.

put into them by him at Lafayette, Indiana, and mailed at once to Madison. The usual time for fixation was from two to three days. Flemming's triple stain gave the best results. Good preparations were also obtained by the use of Heidenhain's haematoxylin.

In the case of Phragmidium, material was found of all ages, so that the entire history from the uninucleated mycelial cells to the fully formed binucleated spores could be easily followed. It was found that in the young pustule the hyphae form a layer just beneath the epidermal cells (*fig. 1*). This layer, in which the direction of the individual hyphae is almost lost, is usually from one to three cells thick. The mycelial cells here are much thicker and shorter than those found in the vegetative hyphae. Each cell has a very dense, finely granular cytoplasm and a single large nucleus. The nucleus occupies a central position in the cell. There is a well-defined nuclear membrane and one large nucleole. The chromatin is always more or less massed at this stage, making a ragged net with the strands very irregular in thickness. Thus a great deal of clear space is left in the nucleus, which is filled with nuclear sap. The chromatin is regularly stained by the violet of the triple stain and the nucleole stains a deep red.

Certain cells now become elongated in a direction perpendicular to the epidermis, forming a continuous series and raising the epidermis (*fig. 2*). The exact origin of the cells of this series is hard to determine; many of them can be seen to be end cells of short hyphal branches. In thick sections, long branches may often be traced between the subepidermal cells of the host, which terminate in one of these cells. In the caeoma the cells are not crowded; there is even considerable intercellular space. Very often it may be seen that cells standing side by side arise from different hyphal branches, or at least from distant parts of the same hypha (*fig. 2*, *a* and *b*).

The single nucleus of the cell now apparently divides and the cell elongates into a rather narrower upper part which is cut off as a small distal cell from the larger basal cell. The cell division is very unequal. The end cell as a result is only about one-third the size of the cell beneath it (*fig. 3*). The protoplasm of the end cell is at first dense and appears quite normal. It soon becomes very vacuolar, however, and finally appears quite clear, with only a few strands of

granular material, and the whole cell dwindles in size. The chromatin of the nucleus seems never to have passed into the resting condition, but lies in dense masses, apparently as it was left on reaching the poles of the spindle in the nuclear division preceding. The whole nucleus is very small compared with the nucleus of the larger cell beneath and contains little space between the chromatin masses. The material of the nucleus begins to disorganize and soon becomes a homogeneous mass, which stains a hazy red with the triple stain.

The cell beneath this terminal cell, on the other hand, begins to enlarge, bulging at the middle, and becomes irregularly barrel-shaped. The cytoplasm is dense with small vacuoles. The nucleus enlarges greatly and the chromatin matter is distributed through its interior, forming a ragged network. There is a large, well-defined nucleole.

We have thus a series of oblong cells standing vertically side by side but not much crowded. If we study a series from the margin of a sorus to its center, we find gradually more advanced stages, so that very many conditions of development may often be found in a single section.

Up to this time in the history, the writer's observations agree very closely with those of BLACKMAN. The subsequent behavior of the larger cells, however, which BLACKMAN terms the fertile cells, is very different. Many times two can be found which incline toward each other, coming in contact in a region on their adjacent walls. At this period the remains of the degenerating sterile cells may often still be seen (*fig. 4*). At the point of contact an opening is formed by solution of the cell wall and thus the protoplasts are brought into contact. The pore is small at first, leaving the bases of the gametes quite independent, and often the two tips of the gametes are also separate, as is indicated by the notch at the apex of the conjugated cells (*fig. 5*). By gradual enlargement of the pore the upper halves of the protoplasts of the gametes unite to form a continuous cell mass which still shows plainly the two distinct bases (*fig. 6*). The nuclei, which before fusion occupied a central position in the fertile cells, now come to lie in their upper portions, consequently the two nuclei are brought side by side in the conjugated region. Simultaneous division now takes place. Two spindles are formed which lie side by side in about

the position in which the pore first appeared (*fig. 7*). The spindles in this division are more distinct and not quite so parallel as in subsequent conjugate divisions. Each shows a few short polar rays and to each pole are drawn several (certainly more than two, though the number was not determined) distinct chromosomes. The two nucleoli are at this time lying in the cytoplasm outside the spindle figures. They are less dense than at earlier stages and appear to be disintegrating. Two of the daughter nuclei, one from each spindle, wander back into the bases of their respective cells. The other two remain lying side by side and move into the distal end of the fused portion of the gametes, which now enlarges and elongates (*fig. 8*). A cell wall now cuts off the distal portion of this region, which contains the upper pair of nuclei, and thus the first aecidiospore mother-cell is formed (*fig. 9*). This cell, as has been described frequently, at once divides into two unequal cells, the aecidiospore and the small intercalary cell.

After one spore has been formed, the nuclei in the bases of the fused gametes again move upward into the conjugated portion, which has meanwhile grown in length, and the process of division is repeated. In this way a single row of aecidiospores is formed from each pair of the gametes (*fig. 10*). During these processes the cytoplasm retains the same granular appearance. The nuclei, excepting in figures showing division, always have the same general structure.

From the fact that the bases of the conjugating cells diverge widely, it is suggested that the conditions shown in *fig. 6* might be produced by the bending of a single hypha, as is the case in the development of an ascus. The earlier development of the gametes, however, shows conclusively that nothing of the sort occurs here, and that the cells which fuse may belong to distinct hyphal branches.

We find thus a typical case of the fusion of gametes at the base of each row of aecidiospores, with the difference that the nuclei do not fuse and the cell produced by the fusion germinates at once. The subsequent history of Phragmidium has been well worked out and I shall not take it up here.

My material of *Caeoma nitens* did not afford so complete a series of stages, but I have been able to trace with perfect certainty the history as far as the formation of the fertile and sterile cells. As in

Phragmidium, hyphae made up of large dense cells collect in layers one to four cells deep just beneath the epidermis of the host (*fig. 11*). From these hyphae a series of large elongated cells is formed which raise the epidermis. A cell wall cuts each of these cells into a sterile cell and the gamete (*fig. 12*).

The remainder of my material of Caeoma was so far advanced in development that each pair of gametes had already formed a considerable series of spores. Here, as in Phragmidium, a most conspicuous structure through all the later stages of the development of the accidium is the basal remnant of the walls which separate the two gametes (see *figs. 6–10*). There may be more or less of it according to the completeness with which the adjacent walls were dissolved away when conjugation occurred, but in all cases it and the two distinct bases remain throughout as an evidence of the double origin of each row of accidiospores (*fig. 10*).

Modifications of *figs. 6–10* sometimes occur when two gametes lie, before fusion, with the entire length of their adjacent walls in contact. A very complete destruction of the walls in the formation of the conjugation pore now may cause the two separate bases of the gametes almost to disappear. A section of *fig. 8*, showing a lateral or edge view, would appear as a single large cell containing two nuclei. Either of these conditions gives us a figure which might readily be mistaken for a binucleated basidium.

In *Uromyces Caladii* Pers. a further interesting modification was observed. In this form the fused portion of the gametes elongates greatly and the two nuclei come to lie in the upper part of this region. Much of the base of this region, and the two basal parts of the gametes, are occupied by a large vacuole (*fig. 13*). By normal conjugate division of the nuclei followed by cell division, an accidiospore mother-cell is formed. The fused portion of the cell is so long and the base is so difficult to trace on account of the vacuole that this also may be readily mistaken for an ordinary binucleated cell.

Blackman considers the process described by him for *Phragmidium violaceum* as a "vegetative fertilization," in which an egg—the fertile cell—is fertilized by a vegetative nucleus, and his conclusions seem justified by the nature of the process in *Phragmidium violaceum*. In *P. speciosum* and *Caeoma nitens*, however, the cells

which fuse are apparently equal gametes. If we consider the matter simply from this standpoint, the whole sorus must be considered as a collection of such pairs of equal gametes. The fusion of each pair should form a zygospore like that of the lower molds. There are, however, two important differences. The product of the fusion in the aecidium is a temporary structure which germinates at once, and further, in germinating it produces a considerable number of spores, the accidiospores, while in the mold normally only one zygospore is produced. If it is found that the same method of fusion occurs in Micropuccinia this form might be considered an intermediate stage between the molds and Eupuccinia.

Further, it seems plain that each pair of gametes with the spores produced by them constitutes an individual structure. The aecidium cup, which has so often been considered the individual fruit body on account of its likeness to the cystocarp or pyrenocarp, is shown, by the discoveries described above, as well as by those of BLACKMAN, to be a complex of coordinate units rather than itself a morphological unit. An ascocarp is the product of the fusion of a single pair of gametes, while the aecidium arises from a collection of many such fusing pairs. Further, the peridium of an aecidium cup is not to be compared to the perithecial wall of the ascocarp, since it is composed of rows of cells which are morphologically equivalent to the aecidiospores. The tissue protecting the asci, on the other hand, is produced by the massing together of vegetative filaments which do not arise from the fertilized egg.

I am convinced that the method of conjugation above described will be found in the forms with the limited cup as well as in the more indefinite aecidial sori of Caeoma. Considering the aecidium a collection of individuals, it would seem that those forms having a peridium are to be regarded as the more highly specialized, while the caeoma is the more primitive type.

Against these views, which seem to me the obvious conclusions to be drawn from my discoveries, it may be urged that the spermogonia with their spermatia, showing as BLACKMAN points out very many resemblances to the male cells of the lichens and the red algae, are still left unexplained, and it must be admitted that there is ground for BLACKMAN'S suggestion of the origin of the rusts from the red algae.

RICHARDS'[2] observations of acarpogonial branch in the young aecidium of *U. Caladii* and other forms favor this view. It is quite possible that the gametes in *U. Caladii* are borne on branches arising from such a carpogonium. The final settlement of these questions of affinity must await the study of further forms of the rusts and related fungi. It is especially important, as suggested above, that the nuclear phenomena in species of rust with an abridged life cycle be determined. There can be no doubt that the proof given above of the existence of a sexual fusion of gametes in the aecidium finally disposes of the conception of DANGEARD[3] and SAPPIN-TROUFFY[4] that the teleutospore is an egg, and the nuclear fusion which occurs in it the equivalent of the sexual fusions elsewhere among the algae and fungi. On the other hand, these discoveries also confirm and give new significance to the conceptions, so clearly set forth by ARTHUR,[5] that the aecidium represents the stage of sexual rejuvenescence. There can be no question that BLACKMAN is in general correct in the contention that the nuclear phenomena in the teleutospore are concerned with chromosome reduction and mark the close of a sporophyte generation which began with the cell fusion in the aecidium. Here again, we need further facts as to the rusts with reduced life cycle before the doctrine of an alternation of generations, such as BLACKMAN maintains, can be regarded as finally established.

MAIRE'S[6] conception that the nuclear fusion in the teleutospore is a *mixie*, was developed on the basis of the belief that no real cell fusion occurs in the life cycle of the rusts. It is at least a fair presumption that while no nuclear fusion occurs in the aecidium, the fusion of gamete cells described above presents all the essential

[2] RICHARDS, H. M., On some points in the development of the aecidia. Proc. Amer. Acad. **31**:255–270. *pl. 1.* 1896.

[3] DANGEARD, P. A., La réproduction sexuelle des champignons. Le Botaniste, **7**:89–130. 1900.

[4] SAPPIN-TROUFFY, M., Recherches histologiques sur la famille des Urédinées. Le Botaniste **5**:59–244. *figs. 69.* 1896–97.

[5] ARTHUR, J. C., The aecidium as a device to restore vigor to the fungus. Proc. Soc. Promotion Agric. Sci., 23d annual meeting.

[6] MAIRE, R., Recherches cytologiques et taxonomiques sur les Basidiomycetes. 1902.

features of sexual conjugations as found in other plants and animals. Superficially considered, RACIBORSKI'S[7] conception that the sexual union may be regarded as consisting of two phases, cell fusion and nuclear fusion, might seem to fit the conditions found in the rusts. I am inclined, however, to accept BLACKMAN'S conclusion that the fusion in the teleutospore has wholly to do with the reduction of the number of chromosomes.

The difference between the method of conjugation in *P. violaceum* as described by BLACKMAN and *P. speciosum* as I have described it above indicates the necessity for a comparative study of a large number of aecidia to determine the nature of the sexual process in the group as a whole. There can be no question, however, that with the discoveries already made the existence of true sexual cell fusions in the rusts is finally established.

The writer feels greatly indebted to Professor ARTHUR for the careful selection and fixation of the material used in this work, and to Professor HARPER for valuable suggestions and kindly assistance in many ways.

THE UNIVERSITY OF WISCONSIN,
Madison, Wis.

EXPLANATION OF PLATE VIII.

The figures were drawn with the camera lucida. *Figs. 1, 2, 10, 11,* and *12* were drawn using the Bausch & Lomb 1-inch eyepiece and $\frac{1}{12}$ oil objective; all others were drawn with $\frac{1}{2}$-inch eyepiece and $\frac{1}{8}$ objective, the tube length in either case being 185^{mm}.

Phragmidium speciosum.

FIG. 1. Hyphae massing beneath the epidermis in the early stages of the caeoma.

FIG. 2. The series of large cells formed preparatory to division into sterile cell and gamete; *a* and *b*, cells lying close together, which appear to be parts of different hyphal branches.

FIG. 3. A cell of such a series as is shown in *fig. 2* after the division into the smaller sterile cell and the large gamete.

FIG. 4. Two gametes about to fuse; sterile cells remain though very much reduced in size.

FIG. 5. Fusing cells with the small conjugation pore just formed.

[7] RACIBORSKI M., Über den Einfluss äusserer Bedingungen auf die Wachstumsweise des *Basidiobolus ranarum*. Flora **82**: 107–132. *figs. 11.* 1896.

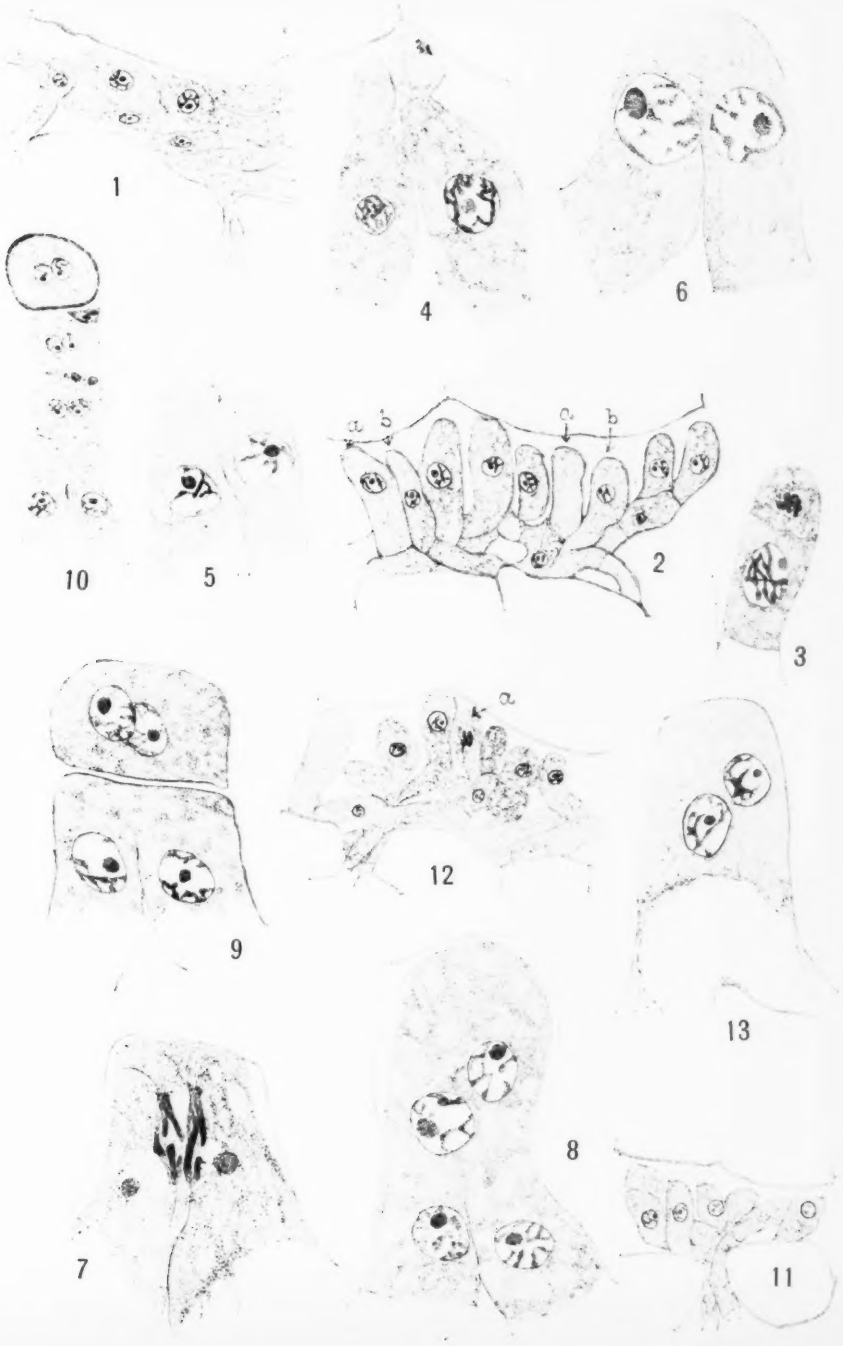
1
4
6
10
5
a
b
a
b
2
3
9
a
12
13
8
7
11

FIG. 6. Same as *fig. 5*, slightly more advanced; the nuclei lie nearer the distal end than in earlier stages.

FIG. 7. Simultaneous nuclear division following the fusion.

FIG. 8. A stage following nuclear division in which the fused mass contains four nuclei, two side by side in the distal end and one in each of the bases.

FIG. 9. The aecidiospore mother-cell formed by a cell wall cutting off the upper portion of the protoplast.

FIG. 10. A figure taken from a thick section showing several aecidiospores, intercalary cells, and the two gametes at the base; the remnant of the basal part of the dividing wall being evident between the two gametes.

Caeoma nitens.

FIG. 11. Hyphae of rust massing beneath the epidermis in very young sorus.

FIG. 12. Series of large upright cells; *a*, a nuclear division preceding the throwing off of the sterile cell.

Uromyces Caladii.

FIG. 13. A pair of gametes fused, showing the nuclei in the upper portion of the protoplast, the large vacuole in the lower part, and the two less conspicuous bases.

THE FORESTS OF THE FLATHEAD VALLEY, MONTANA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXVII.

HARRY N. WHITFORD.

(WITH MAP AND TWENTY-THREE FIGURES)

[*Concluded from p. 218*]

THE undergrowth of the Douglas spruce-bull pine combination is decidedly heath- or prairie-like. In the more open places grass is predominant, and associated with the grasses are *Balsamorrhiza sagittata*, *Monarda scabra*, *Lupinus ornatus*, and *Clarkia pulchella*. The most common bushes are *Prunus demissa*, *Amelanchier alnifolia*, *Opulaster pauciflorus*, and *Symphoricarpos* sp. In places where the rock is near the surface a heath-like appearance is given to the undergrowth by the presence of *Cladonia* sp., *Arctostaphylos Uva-ursi*, *Campanula rotundifolia*, *Selaginella densa*, *Lepargyraea argentea*, and *Pteridium aquilinum;* other forms noted were *Galium boreale*, *Achillea millefolium*, *Holodiscus ariaefolia*, and *Populus tremuloides;* and along the pebbly shores of the lake Crataegus is very characteristic.

On the southern slope of Swan Hill the vegetation conditions found on the exposed slopes of Mission Mountains are approximated, though this area is slightly more mesophytic; and the same may be said for the east side of Swan Lake. Here the shores end abruptly in a range of hills on whose west slope Douglas spruce and bull pine are characteristic, though here and there are scattered groups of western larch. Another meso-xerophytic area on the east side of Big Fork River, not far from the foot of the lake (*map*), has already been mentioned.

The country lying to the south and southwest of Flathead Lake is semi-arid (*fig. 5*), but in favorable situations there is some woody vegetation. A fringe of trees around the borders of the lake contains principally Rocky Mountain juniper, hawthorn, and bull pine; and the same condition is found along Pend d'Oreille River where

a low terrace has been formed. Dry ravines extending back from this lake also have a woody vegetation. The difficulties which trees meet in getting a start in a prairie region should be recognized. A very large majority of the seeds never germinate, and many that do germinate dry out before they have made a good start; and the sod also in many instances prevents the seeds from reaching the soil. The head of a ravine works back during freshets, undermines the prairie sod, and thus disturbs the vegetative equilibrium that had been established, offering a place more or less free from competition. If seeds fall on one of these bare places and do not dry out before the next rain which disturbs more of the soil, they may be buried by the moving soil; the seeds thus having the advantage of being planted and supplied with moisture at the same time. If the conditions remain stable long enough for the plant thus started to establish itself, it may hold its own even though there is considerable movement of the soil in the erosive process. Of course only a few plants out of the number thus established can exist long in the severe conditions of drouth that prevail in these regions.

The large moraine at the foot of the lake is almost destitute of trees (*fig. 5*), but isolated trees of Douglas spruce and bull pine were observed on its northern slope, and around them were a large number of seedlings, nearly all of which, in spite of their needle-like leaves, were nipped off by the cattle. It is very possible that if it were not for the cattle more of the trees would reach maturity, though it is doubtful if the increase would be very appreciable. However, if a slope was slightly more protected from the drying winds and the cattle did not interfere, open stands of both Douglas spruce and bull pine might exist. The hillside near the region shown in *fig. 6* illustrates the point; it slopes to the north, and the part of it under discussion is too high up the cañon of the Pend d'Oreille River to be influenced by proximity to the river, though probably trees near the river are the source of supply for the seeds that stocked the hillsides higher up. The bank is too steep for cattle to maintain a foothold easily, and except along paths young trees are not eaten by them.

As one approaches the forest formation to the north and east from the south end of Flathead Lake, trees become more prevalent, a number of hilly islands (*fig. 5*) in the lake showing an interesting

series of gradations. First there are hills with bull pine and a few Douglas spruce on the north and east slopes and few or none on the exposed slopes; then there are hills where a considerable number of bull pines find favorable conditions for development on the exposed sides of the hill (*fig. 18*), and with these there is some Douglas spruce. On the protected slopes the Douglas spruce becomes more abundant and may even destroy new growths of bull pine by their shade. Another set of hills nearer the forest formations show the south slopes fairly well covered with bull pine and Douglas spruce, while the bull pine has become less abundant on the protected slopes where the western larch element has been introduced. Thus there are all gradations from hills with few or no trees to those that have mesophytic elements on the north slopes. Of course there are many variations; for instance, hills a little to the north of west of the town of Big Fork have their southern slopes almost destitute of trees, while the protected slopes have a stand of Douglas spruce, western larch, and some bull pines. The series may be carried still further. It has been shown that the west slope of Mission Mountains has a forest of Douglas spruce and bull pine, while on the protected slope western larch is the most prevalent, and with it trees like lowland fir, silver pine, and giant arborvitae, which require still more moisture, are found. If the rainfall be sufficient, a mesophytic forest may be found on the exposed as well as on the protected slopes.

It may be well to analyze the conditions that make the so-called protected slopes more desirable for trees. Of course the great factor that prevents tree growth is the lack of moisture. If an annual rainfall of 400^{mm} falls upon a hill similar to those just described, and in gentle showers so that there will be little or no run-off, the water that leaves the soil directly must do so by evaporation, the remainder soaking in and becoming available for absorption. It is obvious that the slopes receiving the strongest insolation and exposed to drying winds will lose the most water by evaporation, and these are the south and west slopes; hence the north and east slopes will have more moisture in the soil. Again, the plants growing on these protected slopes do not receive so much heat and are not exposed to the drying winds, hence do not lose so much water by transpiration; they not only get more moisture but do not need so much to supply

the transpiration streams, therefore trees that require better moisture conditions can exist in these situations.

The sylvicultural habits of Douglas spruce and bull pine remain to be summarized. Douglas spruce has the widest life range of any of the species found in Flathead valley, being found at higher altitudes than any other of the lowland species, with the exception of

FIG. 18.—View of a portion of an island near the south end of Flathead Lake; a park-like growth of bull pine and Douglas spruce is present.

Engelmann spruce. It is found accompanying western larch all through the mesophytic forests of Swan valley, and forms even a greater percentage of the trees in the meso-xerophytic regions, and advances into the prairie sometimes as far as bull pine. However, this power of adaptation is not without an effect upon its form, for in high altitudes and on the border of the prairie region it is dwarfed and sometimes fasciated. In mesophytic conditions it reaches the dimensions of the trees with which it is associated, and even these

trees, though larger than most of the conifers of the eastern states, are small compared with the vigorous trees found in the hemlock-arborvitae-Douglas spruce forests west of the Cascade Mountains. It is in this region of greater rainfall and warmer winter months that Douglas spruce makes its best growth. With its great power of adapting itself to adverse conditions, it has spread through all the Rocky Mountain region as far south as Mexico. While Douglas spruce can adapt itself to varying conditions of moisture, it is very intolerant of shade, in this respect being like western larch, and even requiring slightly more open places in the forest to gain a foothold. Thus the tree will be reproduced only in open places in the forest.

The distribution of bull pine in Flathead valley is more limited than that of either Douglas spruce or western larch. It occurs in open park-like growths on the borders of the prairie formation, with patches of the prairie between (*fig. 18*). In the forest formations in the vicinity of Nigger Prairie there is a close stand of this species (*fig. 14*). Indeed so thick are the trees in certain situations that there is not sufficient light under them for the reproduction of either Douglas spruce or western larch, though young trees of Engelmann spruce and lowland fir can endure the shade. Isolated groups of bull pine are scattered through Swan valley, usually along streams where abundant light can reach them, and in pebbly soils, where other trees have difficulty in maintaining a stand, bull pine is found. Wherever a single tree is found surrounded by other trees it usually overtops them, showing that it probably started before they were present, for it is exceedingly intolerant of shade; it must have open places in which to pass its young stages, and this perhaps accounts for its scarcity in the mesophytic area in deep rich soils. Where found in Swan valley, it is a very healthy tree and very likely would do well in pure stands there if given a chance. In other words, bull pine does not grow in the dry soils on the border of the prairie because it prefers the moisture conditions found there, for it does better in the soils where there is more moisture; it is almost entirely forced out of the latter soils in the struggle for existence with the more successful trees. It undoubtedly demands a greater amount of heat than the other species, with the possible exception of lowland fir, for its altitudinal range is more limited. The highest point at which it was observed on the surrounding mountains was 1375^{m}.

A summary of the relation of the prairie to the forest in this region is as follows: (1) there is less moisture in the prairie soil than in the forest soil; (2) this is due primarily to the smaller amount of rainfall; (3) in the prairie formation forests may exist in certain topographic situations, as along streams and other bodies of water, and on protected hill-sides; (4) in the forest formation prairies exist where the character of the soil is such that it will not easily hold water; by the gradual addition of humus such soils may be changed sufficiently in their water-holding capacity to permit more mesophytic conditions and in some instances a climax western larch-Douglas spruce combination.

Objection may be made to the use of the term mesophyte for plants with xerophytic leaves. WARMING classifies all conifers as xerophytes because they grow in dry soils. In the eastern United States in contrast with the broad-leaved deciduous trees the conifers are undoubtedly xerophytes, comparatively speaking. That is, during the summer months the deciduous tree requires more moisture than the conifers, therefore the deciduous tree is excluded from the dry soils. In the northwestern United States the coniferous forests occupy the mesophytic soils almost to the entire exclusion of the deciduous element. As shown in the discussion on the climatic formations, this is due to a peculiar climate in which the summers are comparatively cool and dry, and the winters comparatively warm and excessively wet. In such a climate the deciduous tree is lacking, except in edaphic situations, on account of the cool dry summers, because with its broad transpiring surface it requires more moisture than it is able to get. The narrow-leaved sclerophyllous trees, on the other hand, while they do not necessarily thrive during the dry summer months, because of their reduced transpiring surface they are permitted to exist, while the broad-leaved deciduous trees cannot. During the winter the reverse is the case, for deciduous trees with their bare twigs are better able to endure severe conditions than are the conifers. On the other hand, if the climate is moist and warm, the conifer is able to do a considerable amount of photosynthetic work. Thus the deciduous tree requires more moisture during the summer months and is consequently more mesophytic at that season; on the other hand, the coniferous tree requires more moisture during the winter months and consequently is more mesophytic at that

time than the deciduous tree. Because of the equable distribution of moisture throughout the year in sufficient quantity in the eastern United States both can exist, although the deciduous element is able to occupy the mesophytic areas almost to exclusion of the coniferous element. In the northwestern United States the conifers, because the climate in which they grow is more suited to them, are able to occupy the mesophytic areas, and hence, so far as that climate is concerned, are mesophytes. Although they may have xerophytic leaves, the structure of the tree as a whole is more mesophytic during the non-growing season than is that of the deciduous tree. Taking the entire year into consideration, for the reasons given above I think that I am entirely justified in speaking of conifers as mesophytes.

III. The influence of fires on the present composition of the forests of Flathead valley.

In the discussion of the forest conditions up to this point little attention has been given to the influence of fires. There is scarcely a section of land in the area investigated that has not been more or less burned over. In some places mere surface fires have run through the woods, scorching the trunks of the trees sufficiently to scar them. In other situations the fires have burned vigorously through small areas killing many of the trees. Still other fires have destroyed completely large areas, leaving many acres with not a single tree. Such is the case on the west slope of the Mission Mountains (*figs. 4, 16, 17*). There are many small clearings made by settlers, who after proving up their claims have deserted the cabins erected upon them (*fig. 19*).

By marshaling the facts collected by a study of the conditions of reforestation in these fire clearings, nearly all stages in the establishment of new mature forests were determined. Studies in similar regions outside of the area plotted have proved very helpful in the interpretation of these conditions. Some important principles must be kept in mind in explaining what plants will first get a foothold in the open places made by fires. These are as follows:

1. The subterranean parts of some plants that are able to sprout from roots or underground stems may not be destroyed by fire. The sprouts of these species will give the burn a decided aspect in a short time.

2. Other things being equal, the plants whose seeds are in the burn first will gain the earliest foothold.

3. Those plants that have seeds there early after fires will be those that have seeds well adapted for distribution.

4. Of the plants that have their seeds equally well adapted for distribution, those with seed-bearing representatives standing nearest the burned area will have the advantage.

5. Again, other things being equal, of those species that have their seeds equally well adapted for distribution and have seed-bearers equally near the clearing, the species that produce seeds most abundantly will be apt to win out in the struggle.

6. The species that can resist fires the best are likely to have left standing in or near the area itself seed-bearing parent plants.

7. The conditions of the soil must be such that it will permit the germination of the seeds that fall upon it. If the soil is too moist, too dry, too poor, or too much shaded, no matter how many seeds fall upon it, none will germinate.

These well-known principles will aid in the determination of the causes of the many complex conditions of forest growth after fires. Before the actual conditions of the clearings are considered, however, the ecological habits of another tree, the lodgepole pine, must be known.

The lodgepole pine covers large areas in Swan valley, sometimes forming almost pure stands. It is able to exist and thrive in those moist areas where it has to compete only with the spruce and its associates. It is found mixed with all the other species in the mesophytic portion of the valley. Toward the borders of the meso-xerophytic areas it is not so prevalent, though signs of it were noted west of Echo Lake and in the mesophytic portions of the west slope of the Mission Range. It does not advance into the prairie formation, however, so far as the bull pine and the Douglas spruce. Its altitudinal range was not investigated. It is difficult to tell whether or not this tree would maintain a stand in the Flathead valley if it were not for the influence of fires. It is intolerant of shade, in which respect it may be ranked with western larch and Douglas spruce, reproducing in open places only. No young trees were noted in the shade, save an isolated poorly developed specimen now and then

in the slight shade of a mature stand of the same species. Probably it is a little less exacting in its light requirements than western larch and Douglas spruce.

The lodgepole pine is a prolific seeder, beginning to bear fruit early in life. Out of twenty trees varying in age from five to twenty years, many had cones. The youngest tree noted with cones was six years of age, one at this age having seven cones. On one tree nine years old fifty cones were counted. It was a common thing to find clumps of trees 3 to 4^{m} high fruiting abundantly. As will be shown below, this habit of fruiting early in life is of very great advantage to this species. Another thing of very great importance is the fact that the cones remain closed in some instances a number of years, thus preserving the seeds. The heat of a fire will open them and liberate the seeds, many of which will escape injury and germinate at once. The lodgepole pine, during its early stages at least, grows rapidly in height, and this gives it some advantage over its competitors. From the measurements of twenty-five specimens each of lodgepole pine, western larch, and Douglas spruce, the average rapidity of growth in height per year is shown to be as follows: lodgepole pine 52^{cm}, western larch 27^{cm}, Douglas spruce 20^{cm}. Although these averages are from rather meager data, they are sufficient to show that the lodgepole pine has by far the most rapid growth.

In contrast with western larch, Douglas spruce, and bull pine, lodgepole pine has poor fire-resisting qualities. Except in old trees the bark at the base is comparatively thin; the cambium layer is thus easily scorched and killed. In this way many whole forests of trees are destroyed by fires that are not intense enough to consume the trunks. It is not an uncommon thing to see acres of dead standing poles of this species that have thus been swept by fire. In showing how successful lodgepole pine has been in obtaining a foothold in the forests of Swan valley, the principles mentioned above must be kept in mind. The rôle that the plants other than conifers play in the reforestation stages will be treated in another connection. In order that the conditions may be understood more clearly, hypothetical cases will be assumed, and when these hypothetical cases are realized attention will be called to them. Suppose a limited area is burned in the midst of a forest in which western larch and Douglas

spruce are the dominating trees, and that these are mixed with lodgepole pine, silver pine, and lowland fir. Suppose that the trees surrounding this area all bear cones, and all have their seeds equally well adapted for wind distribution. Since not one of the conifers found in the region is able to sprout from the roots that would be protected from the fires, all would have to start from seed. Let us suppose

FIG. 19.—A clearing in a lodgepole pine forest in Swan valley; east slopes of Mission Mountains in the background; these slopes have a mesophytic forest of western larch and Douglas spruce.—Photograph by PRAEGER.

that the seeds of all fall in equally favorable places, and that the seedlings that spring up are numerically proportional to the parent trees in the undestroyed stand surrounding the burn. Each species in the forest adjoining the new growth will thus be represented in the burn in the same proportion as it is in the mature stand. If all the young trees grow with equal rapidity, and the natural thinning out is proportionately distributed among the species, the new stand will be just like the old. There are some small burns where this

condition is approximated; of course the proportions are not exactly the same in the old and new stands (*fig. 20*). Granted that any one of the species in the young forest grows more rapidly in its youth than the others, other things being equal it would gain an ascendancy over its neighbors, and in the forest approaching maturity it would have more representatives than in the old forest. As already shown, lodgepole pine bears exactly that relation to Douglas spruce and

FIG. 20.—Young growth of lodgepole pine and western larch in a clearing surrounded by older trees of the same species, both of which have seed-bearing trees; other plants are dwarf maple and a willow, both of which sprout from old stumps; fireweed is also a characteristic plant.—Photograph by PRAEGER.

western larch at least, and probably to the other species, though no measurements were taken for them. In the new forest thus established, lodgepole pine has made a gain on the other species. However, it reaches maturity sooner than the others, and in the old forest it is the first to drop out in the struggle for existence, so that while in the middle-aged forest it may have had some slight advantage, it loses this and often is entirely eliminated from the mature stand.

Many instances were noted, especially in the region outside the plot mapped, in which lodgepole pine was thus being driven out of forests where doubtless it was more prominent in the young stages of development.

Referring again to the original case, it will be seen to be highly improbable that the species in the stand around the hypothetical burn

FIG. 21.—Young growth of lodgepole pine and Engelmann spruce in a clearing of the same species.—Photograph by PRAEGER.

would produce seeds equally well. Some species might not have any seeds at all, and they would form no part in the new forest unless a few seeds are blown into the area from regions where there are seed-bearing trees. The lowland fir during the past two years has produced few if any seeds in Swan River valley. Any burn made in the valley then within two years could not be stocked with seeds of this species. If for instance Douglas spruce or western larch produce seeds more abundantly than any of the other trees, they are likely, other things being equal, to have more representatives in the

new forest than in the old. So if any other tree, lodgepole pine for example, has more seeds than the others, it will increase in numbers in the new stand that is formed. So far as its relation to restocking a burn is concerned, a tree that does not produce seeds might just as well not exist at all.

This leads naturally to another modification of the hypothetical case, in which the forests that surround the burn have only one or two species instead of a number. The result will be that these species are likely to be the only ones found in the burn. Such a condition is seen in *fig. 20*, where the forest that surrounds the clearing is composed mostly of western larch and lodgepole pine, and these species are the predominating ones in the new growth. *Fig. 21* shows a clearing surrounded principally by lodgepole pine and Engelmann spruce, which are almost the only trees present in the new stand. Again, *fig. 22* shows that bull pine, western larch, and Douglas spruce are present in an opening in a mature forest of these species. Another explanation for this, however, is that the area is situated on the border of the meso-xerophytic region where probably no other species could exist, even if their seeds were present.

This leads to still another modification of the hypothetical case. Assuming that the seeds of all the species are present, it is highly improbable that they would find equally favorable places for germination. The case just cited (*fig. 22*) is an instance of where all except western larch, Douglas spruce, and bull pine are ruled out. If the fire burnt out an Engelmann spruce stand surrounded by a less swampy region in which Engelmann spruce, lowland fir, silver pine, Douglas spruce, western larch, and lodgepole pine were present, only Engelmann spruce and lodgepole pine would be able to restock it, for these are the only species that could grow in the swampy situations. An instance of such restocking was noted near the head of the bay-like area of meso-hydrophytic forest southwest of Ross Lake.

Still other conditions of reforestation remain to be explained. Taking the hypothetical area that has been restocked with the seedlings of all the trees in the surrounding forest, and assuming that the young growth is approximately fifteen years of age, the only species of this young growth that would have fruit is lodgepole pine. The cones on this pine would be more or less abundant, and on all

the others the cones would be absent. If a fire should sweep through this young growth, destroy it, and at the same time consume some of the original forest around it, thus extending the limits of the original burn, what would be the result? The extent of the burned area being greater, the seeds of the trees bordering it could not so readily be carried to the center of the burn. But this portion of the clearing would be restocked with the seeds of young lodgepole pines that were destroyed by fire, but whose seeds would be more or less protected from the fire by the cones. Some of the cones would be cracked open by the heat of the fire and the seeds would be liberated. The result would be that the next forest would contain more representatives of lodgepole pine than the former forest, and that they would be more numerous in the center. Indeed this center might contain a pure growth of lodgepole pines. Another such fire in the course of fifteen or twenty years or less would enlarge this area at the expense of the other species. Thus almost if not quite pure forests of lodgepole pines of considerable extent would be established. It is very probable that the mature lodgepole pine forest found in Swan River valley was established in this way (*fig. 23*). The evidence for this is as follows:

1. In no case was a stand of this species found in which there were not noted dead and charred trunks of western larch and Douglas spruce, mostly the former; these because of the thick bark would be the last to yield to the fire. In some instances mature live trees of western larch were observed towering above the younger lodgepole pine forest. In these cases there were isolated specimens of young western larch of about equal age growing with lodgepole pines (*fig. 12*).

2. In nearly all cases these forests grade imperceptibly into more mature forests in which the lodgepole pine element is entirely or nearly wanting. The mature forests of western larch, Douglas spruce, silver pine, lowland fir, and lodgepole pine are in many instances growing in soil that is similar in moisture content. Thus it cannot be said that the difference in the two stands is due to the character of soil conditions.

3. In the meso-hydrophytic situations there is often a gradation from a spruce forest to a mixture of Engelmann spruce and lodgepole pine, the latter stand being much younger than the former.

4. In stands that contain little or no signs of fires, the lodgepole pine element is absent or nearly so.

5. Nearly all stages in the development toward this condition were noted. Thus, *fig. 20* shows a comparatively recent clearing in a young lodgepole pine forest, which is in turn surrounded by a mature forest of western larch and Douglas spruce in which the lodgepole pine element is inconspicuous. *Fig. 12* shows an almost pure growth of this young forest with mature trees of western larch in it. In another place there is a more mature growth in which only charred trunks of larch tell the tale.

For the reasons given above, it is believed that the explanation for the lodgepole pine in the area plotted is the correct one. As before stated, observations were not limited to this immediate region, and many instances might be cited where burned areas similar to those described have become reforested with lodgepole pine. It will not be out of place to repeat that the advantage which it has over the other species in the region is due to its capacity to produce seeds early in life, and its habit of retaining the seeds in its cones for a number of years, thus preserving them for a greater or less length of time. In forests partially destroyed by fire the trees of western larch and Douglas spruce, because of the capacity of their trunks to resist rather severe burnings, will restock the burned areas. Fires of this nature, repeated sufficiently often to prevent any young lodgepoles from becoming old enough to produce cones, will militate against the latter, while Douglas spruce and western larch will have cone-bearing trees on the ground so long as the fires are not too intense. As soon as these are destroyed, then the seed supply is cut off and restocking from that source at least will discontinue.

It will be seen readily that if the fires that have made the lodgepole pine condition possible are repeated every five years, for instance, the young growth forests of that tree will not be permitted to follow each other in procession, for the five-year interval between fires will be too short a time to permit lodgepole pine to produce seeds. Then of course all forest growth will be completely destroyed and the area will not become clothed with trees until restocked with seeds from the neighboring undestroyed forests. The further these are away, the longer it will take for seeds to reach the devastated area. However,

if the interval between the fires is sufficiently long to give lodgepole pine time to produce seeds, after each fire a forest of lodgepole pines will spring up to replace the old. Such fires enable lodgepole pine to perpetuate itself so long as the soil is able to furnish the requisite amount of nourishment, but a checking of fires will in time bring about the normal conditions. This has been done about as follows:

The fires being absent, the lodgepole pine stand is permitted to reach maturity. As it does so, seeds of forest trees in the neighboring undestroyed or partially destroyed stands have had time to spread into the lodgepole pine forests. Seedlings of those trees that can tolerate the shade will get a start at once, if the other conditions are favorable. Thus in many instances silver pine, lowland fir, and Engelmann spruce were noted growing under lodgepole pine stands in Swan valley. Also in the Terry Lake region seedlings of giant arborvitae and western hemlock were observed in similar situations, although, because of the restricted area to which

FIG. 22.—Young growth of western larch, Douglas spruce, and bull pine in a clearing of the same species.—Photograph by PRAEGER.

these two species are confined, their occurrence under lodgepole pine stands is not common. As soon as openings are made in the forest of mature lodgepole pines, due to causes other than fires, this undergrowth may spring at once into prominence and may come to occupy a place in the mature forests. At the same time the openings have made it possible for the existence of seedlings of such trees as western larch and Douglas spruce which demand light for germination. Of course lodgepole pine seedlings can germinate here also, and in the first generation or two they will still predominate; but each new generation will have fewer specimens of the latter species, for since it is not a long-lived tree, a canopy of the mature forest of the other species will in the long run crowd it out by density of shade, or reduce its occurrence to isolated trees here and there in the forests. In this way the forests will revert to the normal conditions. The time it will take to do this depends upon the nature of the conditions that the last fire left. If the lodgepole pine conditions had been established for a wide area, the time would be long, perhaps covering many generations of growth. If on the other hand the fire only partially destroyed the original forest, one or a few generations would suffice to permit the re-establishment of a forest similar to the original. Between these two extremes are all stages, some of which have been described. Indeed the present forest formations are a complex expression of the influence of fires upon them.

The general aspect of a lodgepole pine forest approaching maturity is somewhat different from that of other stands. It has already been shown that the growth in height is rapid. In dense stands of young growth the poles are long and spindling, hence the name lodgepole pine. The small diameter of the bole of the tree is very characteristic. A forest in which the average age of the trees is about one hundred years is seen in *fig. 23*. In this forest, where the trees are over a hundred years old, the average diameter is probably 20^{cm}, many trees being only 15^{cm} in diameter.

Compared with the other forests growing in like situations, the canopy that a lodgepole forest forms is not very heavy. This permits more light to reach the forest floor, hence there is a greater development of undergrowth. It has already been shown that seedlings of silver pine, Engelmann spruce, and lowland fir can endure

the shade of these forests, and that except in open places Douglas spruce, western larch, bull pine, and lodgepole pine are ruled out altogether. The birch is found scattered throughout the limits of the forest. Indeed, as will be shown, it is often a conspicuous tree

FIG. 23.—Mature lodgepole pine forest in Swan valley, showing a dense stand in which the trunks are 15 to 20cm in diameter; the undergrowth consists of *Acer glabrum*, Pyrola, Pteridium, Linnaea, etc.—Photograph by MCCALLUM.

in the burns, and grows up with lodgepole pines, though as the forest matures it drops out early. The undergrowth consists of *Acer glabrum*, *Lepargyraea canadensis*, *Symphoricarpos* sp., *Rosa* sp., *Lycopodium* sp., *Pyrola secunda*, *Pteridium aquilinum*, *Linnaea borealis*, *Chimaphila umbellata*, *Clintonia borealis*, and *Aralia nudi-*

caulis. Scattered specimens of juniper are found in places. In other respects the forest is like the other stands in the mesophytic regions.

In what has been said concerning fires, no mention has been made of species other than conifers. They may often play an important rôle in the first stages in the natural process of reforestation, but their importance diminishes as the life history becomes complete. One of the first plants to give a decided aspect to the forest after fires is the fireweed (*Chamaenerion angustifolium*). The birch and aspen, by virtue of their light seeds, gain an early place in the burns. Indeed sometimes their stands become quite dense and they check the advent of coniferous species. Many species that were on the forest floor of the mature stand may have survived the fires and spring up even more vigorously than before, because the shade has been removed. Especially is this true of those forms that can send shoots from their roots or from underground stems. In the burn on the east slope of the Mission Range south of Big Fork, there are shrubby growths of *Salix* spp., *Ceanothus sanguineus*, *Opulaster pauciflorus*, *Acer glabrum*, and *Holodiscus ariaefolia*, many of which probably were present as underbrush in the stand that existed previous to the burn. These shrubs will retard the reforestation of the area in some instances to a marked degree. If the forest that is destroyed be on the border of the prairie, plants from that association will form an important element in the growth that follows. This is of course detrimental to forest growth. Indeed if the fires be repeated often enough, the forest plants will gradually diminish in quantity, and the prairie element will become more and more prominent, until finally a prairie will come to replace a forest. If the fires be checked, however, for any length of time, the forest will gradually reconquer the territory thus lost. It is probable that some of the prairie region in Flathead valley has been won from the forest in this manner. It must be remembered that in the area bordering on the prairie, in Flathead valley at least, lodgepole pine is not successful and is thus ruled out from playing any important rôle in these places after fires.

In the discussion of the causes for the Nigger Prairie region, mention was made of the importance of the accumulation of humus in rendering the sandy soil more capable of holding moisture. It

can be seen that fires will tend to reduce the humus content of the soil. This is of extreme importance, for that which would otherwise add to the richness of the soil and increase its water-holding capacity is destroyed. Especially is it of importance in those regions that border on the prairie. There is evidence of many such surface fires in the open woods around Nigger Prairie, and it is very probable that these fires have played an important rôle in keeping the prairie vegetation from being encroached upon by the forests that surround it. Even in the mesophytic conditions, fires influence the capacity of the soil to reforest itself quickly, by partially or totally destroying the humus. However, with the reclothing of the burned area, the floor of the new forest will gradually resume its normal condition.

From the above it will be seen that forest fires play an important part in determining the composition of the forest. That forest fires prevailed in this region before the advent of civilized man is a logical inference. In the lodgepole pine forest in the Swan River there are unmistakable signs of fires before the present forest, which is now about one hundred years old, was started. How these fires started can only be conjectured, and it is not within the province of this paper to discuss their origin. It is also very evident that the fires are more numerous since the settling of the country by civilized man than before.

SUMMARY.

1. Fires play an important part in determining the present composition of the forest.

2. The lodgepole pine is the "fire tree" of the region.

3. It is favored after fires principally because it has the capacity to produce seeds early in its life.

4. Many complex conditions of growth are introduced after fire. The species that have seed-bearing trees near the burn will generally be represented in the new forest.

5. Repeated burnings at intervals of ten to thirty years will establish a lodgepole pine forest where formerly there existed a normal mesophytic forest.

6. Repeated burnings at intervals of five years or less will destroy all forest growth.

7. After the lodgepole forest is once established and the fires are checked, it will slowly be replaced by the species that exist in the normal forests.

8. The lodgepole pine is not successful in the bull pine belt.

I wish to thank Dr. H. C. COWLES for many valuable suggestions made in the preparation of this paper; also Professor M. T. ELROD, through whose kindness I was permitted to make the Montana Biological Station headquarters while collecting data; also Professor ELROD, W. E. PRAEGER, and W. B. MCCALLUM for the photographs from which the illustrations were made. The taxonomic nomenclature used in this paper is that found in RYDBERG'S *Catalogue of the flora of Montana and the Yellowstone National Park*, and SUDWORTH'S *Check list of the forest trees of the United States*.

GOVERNMENT LABORATORIES,
Manila, P. I.

BRIEFER ARTICLES.

NOTES ON THE PHYSIOLOGY OF STIGEOCLONIUM.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXX.

(WITH THREE FIGURES)

THE experiments with which this paper has to deal fall into two groups, those with low temperatures and those with sea water. The subject for experimentation was the polymorphic form of Stigeoclonium with which I have been concerned in several preceding papers.[1] As has been already shown, this alga takes either of two very distinct forms according to the nature of the medium in which it is grown. In solutions of relatively high osmotic pressure and in those of low pressure to which stimulating metallic salts have been added, the palmella form is assumed. This consists of nearly spherical cells lying singly or in irregular groups. In unpoisoned solutions of low osmotic pressure the alga grows as branching filaments composed of cylindrical cells. When such filaments are placed in a poisoned solution or in one of high pressure, they become transformed to the other form by the simple rounding off of their individual cells. In general the production of zoospores is checked where the palmella form is produced, but there are a number of exceptions to this among the metallic poisons.[2] In such cases this process may be accelerated even where the germination and growth of the zoospores are inhibited.

I. *Low temperatures.*—Since high pressure of the medium acts to prevent water absorption, and since low temperatures are known to cause the extrusion of water by both plant and animal cells,[3] it occurred to me that

[1] LIVINGSTON, B. E., (1) On the nature of the stimulus which causes the change in form of polymorphic green algae. BOT. GAZETTE **30**: 289–317. 1900.

———, (2) Further notes on the physiology of polymorphism in green algae. BOT. GAZETTE **32**: 292–302. 1901.

———, (3) The rôle of diffusion and osmotic pressure in plants. Chicago. 1903. Part II, Chapter III. This chapter was reprinted as "The effect of the osmotic pressure of the medium upon the growth and reproduction of organisms. Chicago. 1903.

———, (4) Chemical stimulation of a green alga, Bull. Torr. Bot. Club **32**: 1–34. *figs.* 17. 1905.

[2] Loc. cit. (4).

[3] Loc. cit. (3), pp. 75 and 141, and the references there given.

possibly low temperatures might also cause filaments of this alga to take the palmella form. Experiments were devised to test this point, and their results are here given.

Cultures of the filamentous form were made in small glass dishes with loosely fitting covers. The medium employed was the modification of Knop's solution previously described,[4] and had an osmotic pressure of 60^{mm} of mercury. The culture dishes were placed in weighted beakers which floated about three-fourths immersed in ice-water contained in a galvanized iron tank. Ice was added from time to time as melting took place, and the superfluous water was drawn off. The tank was covered with glass and stood in the conservatory, so that the plants were supplied with the necessary light for growth. The cultures were shaded from direct sunlight.

In the medium employed the alga grows rapidly as filaments at laboratory and conservatory temperatures. Zoospores are produced and germinate to form new filaments. Such normal filaments are shown in *fig. 2*. The figures are all from camera drawings and are magnified about 300 diameters. In the cold cultures, whose temperature rarely rose above 6° C.,[5] the growth of the original filaments was checked, but the production of zoospores continued at about the normal rate. At the end of fifteen days the old filaments had completely changed to the palmella form, in the manner already described for solutions of high osmotic pressure. Zoospores fail to germinate normally in the cold; most of them simply lie quiescent on the bottom of the dish, having assumed the spherical form, while a few enlarge slowly and divide into new palmella cells. Growth of the palmella form is comparatively very slow at ordinary temperatures. It is still more so in the cold, and this retardation is here even more marked in resting zoospores than in cells produced by the breaking up of the original filaments. Palmella cells from one of the cold cultures are shown in *fig. 1*. They are seen to be exactly similar to those produced by high pressure or toxic cations. Several resting zoospores and empty sporangia are also figured. That the plant was not permanently injured by the low temperature was shown conclusively by continuing the cultures in the conservatory after they had been taken from the cold bath. They all responded to the return to normal temperature, by producing typical filaments in from ten to fourteen days. A portion of one of these cultures after the filamentous form had been assumed again is shown in *fig. 2*. Germinating zoospores and empty sporangia are also shown.

[4] Loc. cit. (4), p. 4.

[5] During the period of the experiment, 20 days, the temperature was unwittingly allowed to approach 10° C. several times, for periods of a few hours only.

Five cultures made from different stock material, and always compared with controls maintained at the temperature of the conservatory, all agreed perfectly in the results. Thus it seems safe to conclude that *low temperatures act upon the vegetative growth of this alga with the same result as do high osmotic pressure and poison cations.* No acceleration of zoospore formation, a phenomenon often exhibited in poisoned solutions, has been observed here. It appears that in low temperature we have another method of withholding water from the plant, and that the uniform response to such withholding is the production of the palmella form.[6]

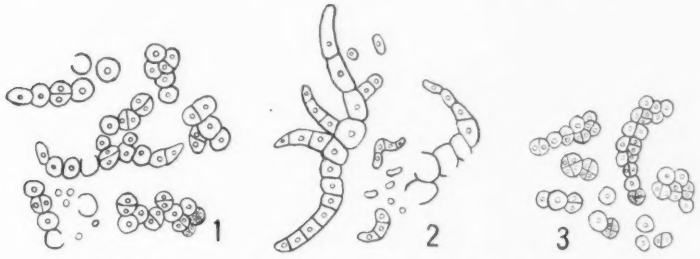

FIG. 1.—Palmella from filaments like *fig. 2* in culture at low temperature.

FIG. 2.—Normal filaments and germinating zoospores from cold palmella culture returned to normal temperature.

FIG. 3.—Palmella in sea water from normal filaments like *fig. 2*.

II. *Sea water.*—During my residence at the New York Botanical Garden I was able to determine the behavior of this Stigeoclonium in sea water. Natural water was collected from the surf at Far Rockaway, L. I., and was brought in bottles to the laboratory, where it was used in making the cultures. Filaments of this plant placed in undiluted sea water take the typical palmella form, as in other solutions of high pressure. Zoospores are not produced, nor do those produced previously germinate. Such a culture is shown in *fig. 3*. The water used had a pressure of about 25,000^{mm} of mercury.[7] In sea water diluted to one-tenth and one-hundredth of its natural concentration respectively—water redistilled in glass being used in the dilution—the response is the same, although the change is not so rapid. In the latter dilution it seems impossible that osmotic pressure is the main stimulating factor, for here is a pressure of only about 250^{mm}

[6] See the remarks on this subject in the paper on chemical stimulation, loc. cit. (4), p. 21 et seq.

[7] The calculation was made by the method of the depression of the freezing-point, loc. cit. (3), p. 37.

of mercury, while a pressure of over 15,000^{mm} is necessary to bring about a marked response in the alga.[8] Perhaps there is a stimulating chemical in sea water which aids the somewhat high osmotic pressure to bring about the result. At a dilution of one-thousandth the filaments grow normally as in weak nutrient solutions.

The result of this test suggests how a fresh-water form coming into sea water may be influenced to change its character and still live and thrive. This may have been a factor in the evolution of certain algal forms.—BURTON EDWARD LIVINGSTON, *The University of Chicago.*

FERTILIZATION IN THE SAPROLEGNIALES.

PROFESSOR B. M. DAVIS,[9] in his criticism of my views "On fertilization in the Saprolegnieae," makes use of the term "ovocentrum" in a sense very different from that which I gave to it. His use of the term, moreover, is obviously based on a misconception of my meaning. He says "TROW calls the egg-asters ovocentra." I neither do this, nor do I approve of it being done. Such an innovation would be worse than useless, as it would increase the confusion which already exists. At present, unfortunately, structures of more than one kind have apparently been grouped together by giving them a common name—"coenocentrum." I suggested the term "ovocentrum" as suitable for use in describing the dense mass of protoplasm found at the center of the eggs of the Saprolegnieae. Imbedded in the ovocentrum of an egg I find a single nucleus accompanied by a single centrosome and its astrosphere. It would have been correct, I think, for DAVIS to have said that the "coenocentra" discovered by him in Saprolegnia were interpreted by me—rightly or wrongly—as consisting of centrosomes with their astrospheres. The "ovocentra" of the Saprolegnieae may be the equivalents of the coenocentra of the Peronosporeae. They are altogether different from centrosomes and astrospheres. I cannot, therefore, accept DAVIS'S statement that I call "the egg-asters ovocentra." I do not propose to discuss the many other points of interest raised by Professor DAVIS, for new facts are required now, and these can only be obtained by patient and prolonged investigation in the laboratory.—A. H. TROW, *Cardiff, Wales.*

[8] Loc. cit. (1) and (2). [9] BOT. GAZETTE **39**:61. 1905.

CURRENT LITERATURE.

BOOK REVIEWS.

The trees of North America

PROFESSOR SARGENT[1] has brought into a convenient volume the information concerning the trees of North America that is much more elaborated in his *Silva*. The sequence is that of ENGLER and PRANTL'S *Die natürlichen Pflanzenfamilien*. Especial attention has been given to the construction of simple analytical keys, so that a species may be determined with the minimum of trouble. For example, the key to the families is based on the arrangement and character of the leaves; and in the same way genera and species are reached by the important and easily discovered contrasting characters. Each of the 630 or more species is further made clear by the admirable illustrations of Mr. C. E. FAXON, showing the leaves, flowers, and fruits. There is no reason why this manual should not become at once extensively used by all those interested in trees, a constituency that extends far beyond the boundary of professional botanists.—J. M. C.

Organic evolution

A RECENT BOOK by Professor METCALF[2] presents in a clear and simple style the fundamental principles of organic evolution in a form very well adapted to the needs of the general reader and to those who wish an outline of the theory of Darwinism. The standpoint is clearly that of the Neo-Darwinist, and the main topics the familiar ones of adherents of this school. Perhaps the most striking feature of the book is the wealth of clear and very well selected illustrations, a large proportion of which are presented for the first time in a general text of this character. These give to the work a character quite its own, and in themselves justify a book which in its general outlines follows very closely the subject-matter and method of presentation in several popular accounts of evolution, including those of WALLACE and ROMANES. The subject-matter is chiefly zoological, and the book would hardly claim an extensive treatment of the principles of plant evolution.—B. M. DAVIS.

MINOR NOTICES.

THE REPORT for 1904 of the Chief of the Bureau of Plant Industry, Dr. GALLOWAY, is commended to the perusal of all botanists that they keep in touch with the botanical work in progress under this Bureau of the Department of

[1] SARGENT, CHARLES SPRAGUE, Manual of the trees of North America (exclusive of Mexico). Imp. 8vo. pp. xxiii+826. *figs. 640*. Boston: Houghton, Mifflin and Company. 1905. $6.00.

[2] METCALF, M. M., An outline of the theory of organic evolution. Imp. 8vo. pp. 204. *pls. 101. figs. 46*. New York: The Macmillan Co. 1904.

Agriculture. It is impossible here to summarize the report, itself a summary. Certainly every American who understands the past success and future plans of this bureau must feel proud that our government is thus leading the world in turning applied botany, based upon researches by a capable staff, to the production of wealth and comfort for the people. As a mere matter of dollars and cents, any one of a dozen or more discoveries made or practically applied by this bureau recently will add to the annual income from our fields and gardens more than the whole bureau has cost from its beginning. The report is a concise and clear showing that will interest all and will surprise those who have not followed closely the recent developments.—C. R. B.

THE BULLETIN from the laboratories of natural history of the State University of Iowa contains in its last issue (Vol. V, no. 4) two botanical papers on the local flora, viz., *The flora of the St. Peter sandstone in Winnesheik Co., Iowa*, by Professor B. SHIMEK: and *The Discomycetes of eastern Iowa*, by FRED J. SEAVER. In the latter, out of nearly one hundred species collected in the state, about fifty are described and illustrated in twenty-five plates, the remainder being reserved for further study. No new species are described.—C. R. B.

THE SECOND ANNUAL ISSUE of the volume on Botany of the *International Catalogue of Scientific Literature*[3] was published in December last, the manuscript having been completed in March 1904. There is no occasion to explain the scope and quality of this publication, for it has already been extensively reviewed,[4] and the opinions of botanists concerning it have become well settled.—J. M. C.

J. PERKINS[5] has issued the third fascicle of contributions to the flora of the Philippines. The collaborators are as follows: C. DE CANDOLLE, Piperaceae; J. PERKINS, Rutaceae; O. WARBURG, Ulmaceae, Moraceae, Urticaceae, Balanophoraceae, Aristolochiaceae, Magnoliaceae, Thymelaeaceae, Ericaceae, and Ficus; E. B. COPELAND, Ferns (38 n. spp. and *Christopteris*, n. gen.).—J. M. C.

NOTES FOR STUDENTS.

RECENT STUDIES IN HYBRIDIZATION.—The literature of Mendelian inheritance has been enriched by the appearance of several important recent papers. TSCHERMAK[6] gives an account of further studies in the hybridization of peas, stocks (Matthiola), beans, etc., which have given him so many noteworthy results reported in earlier contributions. The great amount of interesting detail makes adequate review impossible in a short note. "Kreuzungsnova," which have

[3] International Catalogue of Scientific Literature. M. Botany. 2d annual issue. 8vo. pp. 1111. London: Harrison & Sons, 45 St. Martin's Lane. 1904. 37s. 6d.

[4] BOT. GAZETTE **34**:455. 1902.

[5] PERKINS, J., Fragmenta Florae Philippinae. Fasc. III. pp. 153–212. *pl. 4*. Leipzig: Gebrüder Borntraeger. 1905. *M*5.

[6] TSCHERMAK, E., Weitere Kreuzungsstudien an Erbsen, Leukojen und Bohnen. Zeits. Landw. Versuchsw. **7**:533–638. 1904.

usually been considered uncommon, he has found to result regularly in seventeen of the hybrids that he reports. Races which show the possession of such latent characters that are externalized as a result of crossing he has designated in another recent paper[7] as "cryptomeric" races, and the process of externalization of latent characters as "cryptohybridism." In many cases the new characters are recognizable as atavistic, in other cases they appear to be retrogressive or degressive modifications. The processes by which these arise he calls "hybrid atavism" and "hybrid mutation," and he looks upon the latter as an important source of new forms, especially of "defect-races."

In nearly all cases the new characters as well as the parental characters behaved in a Mendelian way. Thus in a cross between two races of peas, white-flowered × rose-colored gave complete dominance of red (atavistic) in the first generation (F_1) splitting in F_2 to red: rose: white = 9:3:4, the red dominating the rose, and red + rose the white, in the simple ratio 3:1. In a case of this kind the red is called "dominant" and rose "co-dominant." In other cases "co-recessives" occurred, giving four forms in the second generation, the ratio being 9:3:3:1. A still further complication was found in a cross between white-flowered *Matthiola glabra* and red-flowered *M. incana*, in which pure violet dominated in F_1 and five forms appeared in F_2, giving approximately the proportions 27:9:9:3:16. This last result was reported by TSCHERMAK two years ago, and he explained it by assuming that each of the four colors (the fifth class being the white recessives) is a compound, $a+b$, $a+d$, $b+c$, and $c+d$, and on this assumption he predicted then what would be the product of each of these groups in F_3 when self-fertilized. The third generation is here presented, showing that in every instance his prediction was confirmed.

LOCK[8] obtained very similar results in crosses of various cultivated peas with species native at Peradeniya, Ceylon. Thus with respect to seed-color, self-colored × white gave in F_2 self-colored : purple spotted : white = 9:3:4, and another case precisely resembling that of TSCHERMAK's Matthiolas gave categories of seed-coloration in the second generation nearly in the ratios 27:9:9:3:16. The explanation offered by LOCK is essentially the same as TSCHERMAK's, though differently expressed. He assumes that the allelomorphs ABC in the colored pea are matched by corresponding recessives abc in the white, but that neither B nor C can reach external expression except in the presence of A. The chance combinations of gametes containing these allelomorphs then result in the observed ratios.

LOCK's paper gives an admirable general treatment of Mendelism, illustrated with new examples taken from his own studies, and presents briefly but fairly the results of other workers. It can be recommended to any one who wishes to

[7] TSCHERMAK, E., Die Theorie der Kryptomerie und des Kryptohybridismus. Beihefte Bot. Centralbl. **16**: 11–35. 1904.

[8] LOCK, R. H., Studies in plant breeding in the tropics. Ann. Roy. Bot. Gard. Peradeniya **2**: 209–356. 1904.

orient himself with the least possible expenditure of time and effort in the important fields which have been opened up by MENDEL and his belated successors.

EMERSON[9] gives a continuation of his studies in bean hybrids, in which he now treats his results statistically, instead of qualitatively as in his preliminary report two years ago. The numbers are mostly not large, but considering the smallness their agreement with the theoretical ratios is fairly close. The chief interest in EMERSON's results is the class of characters investigated, often making classification difficult, and considerable error probably being introduced in this way. A few of these characters with the dominant member of the pair given first are as follows: running habit (flowers axillary), bush habit (flowers terminal); pods tender, pods tough; pods green, pods yellow. In the case of stringless *vs.* stringy pods, about half the crosses showed the former dominant, the other half being intermediate; though all the progeny from any given cross behaved consistently. EMERSON shows that no prediction can be made regarding the hereditary behavior of seed-color from knowing the relations obtaining in other hybrids having the same seed-color, a fact also noted by TSCHERMAK in the first paper mentioned above.

CORRENS[10] has reported the results of further observations on hybrids of *Hyoscyamus niger*, *H. pallidus*, and *H. major*. The former crossed with its var. *annuus* shows complete dominance of the biennial habit with typical splitting in F_2 and later generations. *H. pallidus* × *H. niger*, which was reported in a previous paper as giving intermediate flower color in F_1, is now shown to split typically in later generations, regardless of the annual or biennial habit of the offspring and independently of evironmental conditions.

CORRENS[11] has also investigated the hereditary relations of gynodioecism, dealing chiefly with *Satureja hortensis* and *Silene inflata*. In the former species bisporangiate flowers crossed together showed a predominance of bisporangiate plants in F_1, but when stigmas of the ovulate plants were pollinated with pollen from bisporangiate plants the offspring were almost without exception ovulate. In Silene the results were very similar, ♀×♀ giving almost entirely ♀, and ♀×☿ resulting in a predominance of ♀. This is quite contrary to Mendelian expectation, and the author does not believe that sexuality can be aligned under ordinary laws governing characters of hybrids, which it will be recalled has been attempted by CASTLE[12] with reference to animals.—G. H. SHULL.

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[9] EMERSON, R. A., Heredity in bean hybrids. Ann. Rept. Agr. Exp. Sta. Nebraska **17**:33–68. 1904.

[10] CORRENS, C., Ein typisch spaltender Bastard zwischen einer einjährigen Sippe des *Hyoscyamus niger*. Ber. Deutsch. Bot. Gesells. **22**:517–524. 1904.

[11] CORRENS, C., Experimentelle Untersuchungen über die Gynodioecie. Ber. Deutsch. Bot. Gesells. **22**:506–517. 1904.

[12] CASTLE, W. E., The heredity of sex. Bull. Mus. Comp. Zoöl. **40**:187–218. 1903.

PENHALLOW[13] has recently published the first and general part of an extensive treatise on the anatomical determination of the North American Coniferales as well as certain species from Japan and Australia. The memoir represents the results of a quarter of a century's work in this field and is of great importance from the paleobotanical and phylogenetic standpoints. Although the author expresses his appreciation of the value of a general anatomical study of the group, he limits himself to the structural features of the ligneous cylinder, for the reason that coniferous remains are ordinarily best preserved as fragments of wood. Wood structure is discussed under the following headings: spiral tracheids; bordered pits, distribution and structure; medullary rays; resinous tracheids and resin cells; and resin passages.

Under the caption of bordered pits, the author points out that multiseriate and crowded pits deformed by mutual pressure are characteristic of the older gymnosperms, the Cycadofilices, Cordaitales, etc. Bordered pits are in general confined to the radial walls of the tracheids, exceptions to this mode of distribution occurring only in the primary wood and in the autumnal tracheids of the annual rings. Under the heading of medullary rays, the various types of structure which are of diagnostic importance are clearly and definitely described, and in this respect the present work marks a long advance on its predecessors. Two types of ray are distinguished, namely the linear ray made up of a single series of cells, and the more complex fusiform ray, which is so broad as to contain a horizontal resin canal. Resinous tracheids are described as diagnostic for the Araucarineae, but also occur sporadically in certain species of Abies. Resin cells, according to the author, appear in the more primitive conifers (exclusive of the yew-like Taxineae) and are characterized by their scattering, zoned, or segregated distribution, the latter condition being considered the most specialized. Where the resin-cells are highly segregated they may give rise schizogenously to resin cysts of limited extent, with walls constricted at intervals. Resinous cysts are found characteristically in the abietineous genera Tsuga and Abies, but also occur in living and extinct Sequoias. In the abietineous genera Larix, Pseudotsuga, and Picea, the resin spaces form a continuous system of vertical and horizontal passages, which according to the author betray their derivation from resin cysts by the constricted character of their walls. In Pinus the resin passages no longer show signs of constriction and are moreover lined entirely with thin-walled epithelium.

The author, as the result of plotting frequency curves based on the occurrence of the various characters of the wood, reaches certain conclusions as to phylogeny which may be briefly stated as follows: The Taxaceae are the oldest of the Coniferales, and from their general plexus have branched off on the one hand the Podocarpeae, and on the other the common trunk, which gave rise to the Taxo-

[13] PENHALLOW, D. P., The anatomy of the North American Coniferales together with certain exotic species from Japan and Australia. Part I. American Nat. **38**: 243–273, 331–359, 523–554, 691–723. 1904.

dineae, Cupressineae, and Abietineae in approximately ascending order. The Araucarineae, contrary to the usual opinion, have a separate and direct origin from the Cordaitales. The conclusions reached by the author from the study of wood harmonize on the whole very well with those adopted in general taxonomic works such as Engler and Prantl's *Die natürliche Pflanzenfamilien*, and are based on the assumption that greater complexity of structure is necessarily characteristic of more modern forms. There is of course room for difference of opinion on this subject, in view of the evidence of general paleobotany, comparative anatomy, and development, which seems to show that the Coniferales form a series of recession rather than of progression. There can be no doubt, however, as to the very important character of the facts brought out by the investigations of Professor PENHALLOW, and the second part of the memoir, which is to contain the specific determinations of the conifers from the structure of their wood, will be awaited with interest.—E. C. JEFFREY.

JEFFREY[14] has published the second of his contributions to our knowledge of the anatomy of the Coniferales, in so far as it bears upon relationships and phylogeny. The immense service that anatomy of this kind is rendering to morphology that concerns itself with phylogeny cannot be overestimated. The student of gymnosperms is particularly indebted to JEFFREY for the studies he is just now prosecuting, for this new method of attack could not have been directed more usefully than upon Coniferales. In the preceding number of the series the author has reached the conclusion that Sequoia shows an abietineous origin, and it was natural that a presentation of the Abietineae should follow. No better summary of his results could be given than that prepared by the author himself; and since the subject is one of much general interest and importance no apology is needed for reproducing it here.

1. The Abietineae are divisible, on the evidence supplied by a study of their vegetative and reproductive organs, into two distinct subfamilies, viz., the Pineae and the Abieteae.

2. The Pineae are characterized by the invariable presence of resin canals, forming an anastomosing system in the secondary wood and cortex of root and shoot. Resin canals are present in the outer margin of the primary wood of the root. The scales of the female cone are not deciduous. Pinus, Picea, Larix, Pseudotsuga.

3. The Abieteae ordinarily do not possess resin canals in the secondary wood of root and shoot. Resin canals, however, are sometimes found in the wood of the female reproductive axis, and in the first annual ring of vigorous shoots of sexually mature trees. Resin canals occur in the secondary wood in tangential rows, as a result of injury. Resin canals are invariably found in the center of the primary wood of the root. The scales of the female cone are generally deciduous. Abies, Pseudolarix, Cedrus, Tsuga.

4. The evidence derived from anatomy and experimental morphology goes to show that the presence of resin ducts in the woody tissues and in the cortex of the Abietineae

[14] JEFFREY, EDWARD C., The comparative anatomy of the Coniferales. Part 2.—The Abietineae. Memoirs Boston Soc. Nat. Hist. **6**: 1–37. *pls. 1–7.* 1904.

is primitive for the group. The resin canals persist longest in the reproductive axis, the leaf, and the *first* annual ring of root and shoot. In the more specialized genera the resin canals of the wood are replaced by resin cells, but in the latter condition of the wood, resin canals may always be recalled as a result of injury. The disappearance of resin canals and their replacement by resin cells is probably for the sake of economy of carbohydrate material. In Pseudolarix and Tsuga even the cortical resin canals disappear from all organs except the female reproductive axis, together with its appendages, and the vegetative leaf.

5. The Abietineae are an older group than the Cupressineae, in the larger sense, and are either antecedent to these or from the same ancestry. This conclusion is reached from an anatomical and experimental morphological study of their organs, root, shoot, and leaf. It is confirmed by the examination of the female reproductive organs and of the pollen. It is further in conformity with paleontological evidence.

6. The Abietineae are throughout characterized by the same double leaf trace which is a constant feature of the older gymnosperms, the Lyginodendreae, the Cordaitales, the Ginkgoales, and the Cycadales. This feature serves to separate them from the Cupressineae in the larger sense, and to unite them with the Cordaitales, which they resemble in other important particulars, described in the body of the memoir.

7. The Abietineae must be regarded on comparative anatomical and morphological grounds as a very ancient order of the Coniferales, and may even be the oldest living representatives of this group.—J. M. C.

SKOTTSBERG,[15] botanist of the Swedish Antarctic Expedition of 1901-1903, gives a preliminary report on the phytogeographical conditions in the Antarctic regions. He proposes for the lands south of 40-50° S. the following names: *Austral* zone, including Terra del Fuego, with the Isla de los Estados, the Falkland islands, South Georgia, and no doubt the South Sandwich islands; and *Antarctic* zone, including South Orkney and South Shetland islands, and Graham Land. An objection must be raised against the use of the terms Antarctic and Austral for local geographical areas such as the author is speaking of. The reviewer had recently (in a paper read before the Philadelphia meeting of A. A. A. S. 1904) occasion to mention in passing that the name of Austral zone for a certain phytogeographical area of North America was incorrect, and he holds a similar opinion in regard to SKOTTSBERG'S use of the term. What is to be called the Austral zone? Certainly not a limited area in South America with a few neighboring oceanic islands. We have at present an almost endless number of phytogeographical divisions, and this is not the place to enter upon a discussion of the relative merits of these, but it seems proper here to point out that if we are ever to get a consistent nomenclature in phytogeography it will not do to apply to local or minor areas names generally used to designate larger divisions. The Arctic region is recognized by DRUDE and ENGLER, for example, as a subdivision of what the former calls the Northern realm and the latter the North extratropical realm. MERRIAM gives to this Northern realm the name Boreal region. The reviewer

[15] SKOTTSBERG, C., On the zonal distribution of South Atlantic and Antarctic vegetation. Geographical Journal 655–664. 1904.

would call it the Boreal realm, of which the Arctic region constitutes a part. In the southern hemisphere we have a corresponding Austral realm, of which the Antarctic region is a subdivision. What SKOTTSBERG now calls the Austral zone is a region that may be designated as Patagonian, or Fuegian, or Magellanian, or by some other local name, and which is a division of equal rank to the Antarctic, subordinating this and several other regions under the term Austral realm. Our criticism here refers to the use of the terms only, not to the author's definition or limitations of the areas under consideration. In regard to the flora of the South Atlantic ocean, the author considers that the division into Austral and Antarctic is just as evident as in the land flora. Until the detailed results of the expedition are made known and until this question is thoroughly discussed, final judgment in the case must be reserved.—OLSSON-SEFFER.

IN A PAPER READ before the B. A. A. S. last August, CZAPEK presents[16] a fuller account of his researches on the anti-ferment reaction which occurs in tropistic movements, especially of roots. In geotropically stimulated roots, for instance, homogentisinic acid, a product of decomposition of tyrosin by tyrosinase, accumulates slightly, instead of being oxidized at once, because an anti-enzyme is produced by the stimulation, which inhibits the action of the oxidase. The quantitative determination of the homogentisinic acid is not practicable as a measure of the reaction, but a solution of homogentisinic acid may be used as a reagent for determining by titration the retardation of its oxidation by the anti-oxidase. The roots to be tested are ground in water with powdered glass to a thin paste, and a standard solution of homogentisinic acid added; the initial reducing power of the wash is determined. and repeatedly at intervals of five days, by titration with $n/10$ $AgNO_3$. CZAPEK finds that only tropisms produce the anti-enzyme; narcosis, poisoning, mechanical hindrance of growth, and wounding having failed by themselves to produce the reaction. Six minutes was determined to be the limit for roots placed horizontal at 17° C. to show the anti-enzyme reaction, which persists for about four hours. Though not observably intensified by prolonged stimulation of the root, it persists for a much longer time, even up to thirty hours after fifty minutes stimulation. The reaction becomes certain for thirty minutes induction at an angle of 7° from the normal and at 10° is maximal, remaining constant up to 170°; decreasing very much at 176°, and not showing at all at 180°. By reducing the time of induction it can be shown that the reaction is stronger at 135°–150° than at horizontal, which assists in settling a disputed point. Roots rotated on the klinostat show the reaction, clearly supporting the view that geotropic stimulation occurs under such conditions though curvature does not result. This reaction also confirms CZAPEK's experiments with glass slippers, showing that more than the root cap with its statolith cells is involved in the geotropic phenomena. He lists these phenomena (assuming them to be consecutive) thus:

[16] CZAPEK, F., The anti-ferment reaction in the tropistic movements of plants Ann. Botany **19**:75–98. 1905.

(1) statolith effect; (2) anti-ferment reaction; (3) the processes hindered by shock; (4) transmission of stimulus; (5) curvature.—C. R. B.

A NOTABLE FEATURE of the recent meetings of the affiliated scientific organizations at Philadelphia was the annual discussion before the American Society of Naturalists, which this year had for its subject the mutation theory. Two of the seven addresses were botanical, D. T. MACDOUGAL opening the discussion from the standpoint of plant-breeding, and L. H. BAILEY presenting the taxonomic bearing of the theory. In the opening address MACDOUGAL[17] stated the main thesis of the mutation theory thus: "the saltatory movement of characters, regardless of the taxonomic value of the resultant forms," its principal corollary being "that the saltations in question do result in the constitution of new species and varieties." He believes that many current misconceptions regarding species are due to the failure to discriminate between elementary species and the composite or "group" species of the systematist; and that there is accumulating evidence that the supposed deleterious effects of close-fertilization are groundless. Warning is given of the confusion which must arise through the unguarded use of the terms "mutation" and "variation" to designate phenomena of segregation and alternative inheritance in hybrid strains. It will be recalled in this connection that in a previous paper MACDOUGAL[18] has discussed the difference between fluctuating and mutative variations, and has included as mutative variations only "newly arisen and transmissible qualities," emphasizing the fact that it is a pure presumption to designate any aberrant condition a mutation until its hereditary character has been demonstrated. Regarding the causes of mutations little is known, but the results of the mutation cultures both at Amsterdam and at New York are held to indicate that they arise in greater numbers under environmental conditions which are especially favorable for vegetative development and seed-production. Some mutations occur much more frequently than others, and the highest total number of mutants found in any progeny of *Onagra Lamarckiana* in New York was over six per cent., as compared with the five per cent. maximum observed by DE VRIES in Amsterdam. Report on other mutating species is promised for the near future.—G. H. SHULL.

THE ECONOMIC importance of LUTHER BURBANK'S achievements in plant breeding, and a certain mystery which has surrounded his work owing to his inability or unwillingness heretofore to impart information regarding the methods he uses, have won for him the appellation "wizard of horticulture." An attempt[19] to present to the public an account of the methods employed and some of the results obtained is welcome, and the name of President JORDAN adds to the

[17] MACDOUGAL, D. T., Discontinuous variation and the origin of species. Torreya **5**: 1–6. 1905.

[18] MACDOUGAL, D. T., Mutation in plants. Amer. Nat. **37**: 737–770. 1903.

[19] JORDAN, D. S., Some experiments of Luther Burbank. Pop. Sci. Monthly **66**: 201–225, *figs.* 22. 1905.

authoritative character of the account. The presentation is given in the form of quoted paragraphs from conversations with BURBANK, and the assurance is given that these have been referred to him for verification. This method certainly has advantages which to some degree counterbalance the disconnectedness and the frequent repetition of ideas which necessarily result from it. There is nothing new or unusual in the methods employed by BURBANK, namely, "selection, crossing, hybridization, and mutation," and it is apparent that his success is dependent upon his great activity rather than upon the methods used. This paper is of great scientific interest but of little scientific value, and emphasizes with unusual force the difference between the economic and scientific ideals. It will be a source of information to scientists, but certainly of a great deal of misinformation to the general public, with whom the source of the statements made will carry a weight wholly incommensurate with their scientific value. It appears to the reviewer that the compiler of these paragraphs from BURBANK'S conversations owed it to his readers to explain two features of the technique employed which would lead to a correct valuation of the statements made. "Strawberry-raspberry hybrids" cause less surprise when it is known that insufficient precautions were taken to prevent the entrance of foreign pollen of unknown origin; similarly, when apple-trees grow from blackberry seeds it is well to bear in mind that the seeds were sown in unsterilized soil. The discussions of the mutation theory and other subjects bearing upon evolution will prove amusing.—G. H. SHULL.

ITEMS OF TAXONOMIC INTEREST are as follows: EDITH M. FARR (Contrib. Bot. Lab. Univ. Penn. **2**:417–425. 1904) has described a new species of Pachystima from the Selkirks of British Columbia.—W. A. MURRILL (Bull. Torr. Bot. Club **31**:593–610. 1904), in his ninth paper on the Polyporaceae, has described *Laetiporus*, *Trichaptum*, and *Pogonomyces* as new genera.—J. A. SHAFER (Torreya **4**:177–181. 1904) has separated a new species of Cassia (*C. Medsgeri*) from *C. marilandica*.—In continuing their account of the flora of western Australia, L. DIELS and E. PRITZEL (Bot. Jahrb. **35**:161–528. 1904) describe numerous new species and also a new genus (*Psammomoya*) of Celastraceae.—EDWARD L. GREENE (Leaflets **1**:81–96. 1904) has segregated from Streptanthus many of the Californian plants that have been referred to it, and has established the following genera to include them: *Euclisia* (14 spp., 3 new), *Pleiocardia* (9 spp., 2 new), *Mitophyllum*, *Microsemia*, and *Mesoreanthus* (3 spp., 2 new); has replaced *Chlorogalum* Kunth by the older *Laothoe* Raf.; has recognized *Aloitis* Raf. as represented by *Gentiana quinqueflora occidentalis* and adds two new species; and has described new species of Batrachium (2) and Sophia (2).—B. F. BUSH (Trans. Acad. Sci. St. Louis **14**:181–193. 1904) has monographed the Texan species of Tradescantia, recognizing 18 species, 10 of which are new.—P. A. RYDBERG (Bull. Torr. Bot. Club **31**:631–655. 1904), in his 13th "Studies on the Rocky Mountain flora," has described new species in Dodecatheon, Gentianella, Gilia (6), Polemonium (2), Lappula (2), Oreocarya (2), Mertensia (6), Stachys, Mon-

ardella, Solanum, Pentstemon (3), Castilleia (3), Valeriana (2), Coleosanthus, Grindelia (2), Gutierrezia (2), Chrysopsis (4), Solidago (6), Oligoneuron, Chrysothamnus (2), and Aster (5).—J. M. C.

LYON[20] has stated more in detail his views as to the phylogeny of the cotyledons of angiosperms. The monophyletic origin of angiosperms is argued with considerable fullness; a view which recent anatomical studies have helped to establish, and to which there is probably little dissent at present. The cotyledons are regarded as primarily haustorial organs, related phylogenetically to the so-called foot of bryophytes and pteridophytes; a view which seems to be well taken and cogently argued. The monocotyledonous condition is claimed to be the primitive one among angiosperms, the dicotyledonous condition being derived from it through the "bifurcation" of the originally single cotyledon. This last view is probably the only one that will meet serious opposition, since the recent studies of the comparative anatomy of the vascular systems of the two groups have contributed great strength to the view that monocotyledons have been derived from dicotyledons. However, this detail does not affect the general claim as to the nature of cotyledons. Beginning with the sporophyte of bryophytes, in which the body is differentiated into two regions called "sporophore" and "haustrum," the latter is traced through into the angiosperms and shown to include cotyledon, hypocotyl, and primary root. In fact, the hypocotyl is regarded as a new "haustral" structure that is differentiated between the root and the sporophore. The term "protocorm" is used instead of "proembryo" for the undifferentiated embryo, and "metacorm" for the "plant body after the differentiation of its permanent members." The author announces that a paper is in preparation in which he "will endeavor to demonstrate the validity of his hypothesis concerning the phylogeny of the cotyledon."—J. M. C.

NĚMEC has brought additional facts to the support of the statolith theory of geotropic perception.[21] Roots from whose tips 1^{mm} has been cut show geotropic curvatures after 20 hours, because the regenerating tip consists of cells with large mobile starch grains. Roots with 1.5^{mm} removed remain straight, having no such new cells. The regeneration of the perceptive complex is not always complete before the root becomes geotropic, certain older cells often acquiring motile starch grains and perceptive sensitiveness. He also adduces further evidence from the behavior of inverted root-tips and replies to objections based upon the results with glass-capped roots, where thigmotropic curvatures (this in the face of NEWCOMBE'S results) may enter. Against CZAPEK'S objection, that the chemical differences between stimulated and unstimulated roots are observed whether the statocysts are present or not, it is suggested that there

[20] LYON, HAROLD L., The embryo of the angiosperms. Amer. Naturalist **39**: 13–35. 1905.

[21] NĚMEC, B., Einiges über den Geotropismus der Wurzeln. Beihefte Bot. Centrlbl. **17**:45–60. 1904.

may be two kinds of perception, of which that by heavy starch grains alone leads to curvature, the other (*e. g.*, by radial pressure) leads to the chemical changes —a strained answer. After defending his ideas against some criticisms by NOLL and by MIEHE, he pays his compliments to WIESNER's objections based on *Clivia nobilis* and *C. miniata*, the former being geotropic, while the latter is not. But NĚMEC finds both confirm the statolith theory, inasmuch as in *C. nobilis* there is abundant motile starch in the perigonial leaves, and none in *C. miniata*. Statolith starch is found widely distributed in mosses. It is wanting in certain geotropic liverworts (*Metzgeria furcata*), abundant in the strongly geotropic *Trichocolea tomentella*, and scarce in the weakly geotropic *Plagiochila asplenioides*.—C. R. B.

STRASBURGER[22] gives a popular but strictly scientific discussion of the genus Alchemilla as it occurs on the Grand Salève at Geneva. At least thirty-one species of this genus are found on this one mountain where LINNÉ recognized only three. No wide gaps separate these species, but their distinctive characters are fully constant in inheritance. The author contrasts the Linnean conception of species as an abstraction with the present conception in which a species is a real entity which he defines as a group of individuals that agree among themselves, and are separated from other species by definite characters that they inherit, however slight these characters may be. The species of Alchemilla are believed to be the result of a rather recent period of mutation, the evidence of its recency being found: (*a*) in the want of marked gaps between the species, which would result through the extinction of some species by natural selection; (*b*) the almost perfect development of stamens rendered functionless by the apogamous habit of nearly all species; (*c*) the marked development of nectaries that are likewise functionless and secrete no nectar. The species are regarded as apogamous rather than parthenogenetic since no reduction of the chromosomes occurs. No case of parthenogenesis in this sense is yet known among higher plants. Alchemilla is paralleled with two other noteworthy apogamous genera, Taraxacum and Hieracium, both of which likewise show numerous elementary forms, and it is suggested that the apogamous habit of these genera may have resulted through excessive mutation that introduced continuous hybridizations with attendant deterioration of the sexual processes.—G. H. SHULL.

IN AN ADDRESS before section K of the British Association, WARD[23] has given an extremely interesting review of the growth of our knowledge of parasitism among the fungi and bacteria, from the researches of DEBARY to the present time. The first part of the paper deals with the more important earlier discoveries which have marked distinct phases or epochs in the advancement of this subject, notably those of A. BRAUN, DEBARY, TULASNE, COHN, KOCH, and others.

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[22] STRASBURGER, E., Unserer lieben Frauen Mantel. Eine phylogenetische Studie. Naturw. Wochenschr. **20**: 49–56. 1905.

[23] WARD, H. MARSHALL, Recent researches on the parasitism of fungi. Ann. of Botany **19**: 1–54. 1905.

The latter part of the paper is occupied principally with questions brought out by recent discoveries and theories relating to the rusts. It is shown that the uredo stage is probably responsible for the wintering of many rust fungi whose distribution and annual recurrence is not easily explained by the regular alternation of teleuto- and aecidiospores. Specialized races, immunity, susceptibility, and related subjects are discussed. The mycoplasm theory of Eriksson is considered to be without foundation and absolutely erroneous in the light of the speaker's investigations. Students will find this a valuable paper for reference, outlining briefly the main questions that have occupied the minds of investigators at different periods in the development of mycology, while the bibliography of 209 titles is a means of easy access to the literature of the subject.

ERIKSSON[24] also read a brief paper on the vegetative life of the Uredineae. This paper is a review of his mycoplasm theory, mainly as set forth in his former papers.—H. HASSELBRING.

CAMPBELL[25] discusses in detail and combats BOWER's theory that the spike of Ophioglossum is the equivalent of a single sporangium of Lycopodium and that all pteridophytes are reducible to a common strobiloid type. He repeats his belief, hitherto published, that the progenitor of the large-leaved ferns may have sprung from some bryophyte type, and that the Ophioglossaceae may have arisen directly from an Anthoceros-like prototype. He regards a species of Ophioglossum from Sumatra described by BOWER (Ann. Bot. **18**:205. 1904) as nearly realizing the hypothetical form suggested by him as the fern ancestor. The close relationship of the Ophioglossaceae and the Marattiaceae is pressed upon the grounds of structural resemblances in both gametophyte and sporophyte, and the conclusion is drawn that there is "no valid reason for removing the Ophioglossaceae from their association with the ferns." He also reviews the evidence offered by recent writers in regard to the likeness existing between the Marsiliaceae and the Schizaeaceae. He thinks there is a marked resemblance between the sporocarp of certain of the former group and the fertile leaf segment of Schizaea, both as regards structure and the origin of the sporangium. These features combined with "the remarkable correspondence in the structure of the sporangia" he considers sufficient evidence to ally the Schizaeaceae and the Marsiliaceae not remotely.—FLORENCE LYON.

IN CONTINUATION of his experiments with the Erysiphaceae SALMON[26] has established that injury to plants in various ways makes such plants susceptible to biologic forms of Erysiphe to which they are normally immune. The fungus

[24] ERIKSSON, J., On the vegetative life of some Uredineae. Ann. of Botany **19**:55–60. 1905.

[25] CAMPBELL, D. H., The affinities of the Ophioglossaceae and Marsiliaceae. American Naturalist **38**:761–775. *figs.* 9. 1904.

[26] SALMON, E. S., Further cultural experiments with "biologic forms" of the Erysiphaceae. Ann. of Botany **19**:125–148. 1905.

used was the biologic form of *E. graminis* on wheat. This form will not infect rye, but by subjecting rye leaves to various treatments it was found that the fungus could be made to infect this plant also. When leaves of rye were injured either by cutting or bruising or by slugs, the cells around the injured parts could be infected with conidia or ascospores from *E. graminis* on wheat. Other experiments showed that rye leaves subjected to the influence of alcohol, ether, or heat become susceptible to infection from conidia taken from wheat. In some of these cases the fungus produced vigorous growth nearly covering the leaves. Conidia grown on barley in this way retained the power of infecting their original host, but were unable to infect normal untreated leaves of barley. These experiments are especially interesting, since they contribute an experimental proof to the generally current notion that plants of "weakened vitality" are more easily attacked by fungi than vigorous plants. The experiments show that at least in certain cases plants may become more susceptible as a result of injurious agencies affecting the general health of the plant.—H. HASSELBRING.

THE COMPLETED FORM of CLINTON'S[27] monograph of the North American Ustilagineae has recently appeared. This monograph is the result of studies carried on for a series of years at the University of Illinois and completed at Harvard University. The descriptions are based on the author's personal examination of type material so far as this was possible. To the technical descriptions are appended notes of interest giving the distribution of the species, and special characters of aid in separating closely related species. Complete synonomy and references to exsiccati are given, while a bibliography of over 200 titles is found at the end of the volume. A feature of the book is the tabulated list giving the distribution by continents of the species treated in the work. This volume forms an excellent handbook for the study and determination of the smuts of North America. It will prove extremely useful to students and station workers by whom the lack of monographs of groups of parasitic fungi has been long felt. It would have added to the utility of the work to have had the index of hosts arranged alphabetically, with page references for the parasites; instead of classifying the hosts according to orders, which is a time-robbing arrangement.—H. HASSELBRING.

GOEBEL[28] has previously shown that *Bryophyllum crenatum* will develop shoots from the growing region at the margin of the leaves if the midrib be severed, or if all the buds be removed from the shoot. Further studies[29] show that the same result follows if the buds be left intact, but inhibited from growing. All the

[27] CLINTON, G. P., North American Ustilagineae. Proc. Boston Soc. Nat. Hist. **31**: 329–529. 1904.

[28] GOEBEL, K., Ueber Regeneration im Pflanzenreich. Biol. Centralbl. **22**: 418. 1902.

[29] GOEBEL, K., Morphologische und biologische Bemerkungen. 14. Weitere Studien über Regeneration. Flora **92**: 132–146. *figs. 6.* 1903.

growing points of several shoots were encased in plaster, and after four weeks' time buds appeared along the margin of the leaves. Upon removing the plaster the buds of the shoot continued growing. In this plant the leaf buds arise from already existing growing points. In Begonia, however, none of these are present on the leaf, and here also continued removal of the growing point of the shoot resulted in the development of buds on the leaves.

In *Streptocarpus Wendlandi* when the inflorescence is removed a number of the adventitious shoots develop. The interesting feature about these is that they present seedling characters, viz., each has a short shoot-like axis and one large leaf corresponding to the large cotyledon, the opposite leaf being almost invisible or entirely suppressed.—W. B. McCallum.

Leclerc du Sablon[30] finds that the carbohydrate and nitrogenous reserve foods of trees reach their maxima in the autumn, and their minima in May or June after the formation of the leaves and shoots of the season. For carbohydrates the roots are more marked reservoirs than the stems, and the leaves do not function as a storage place. Nitrogenous reserves, however, are more abundant in leaves than in stems or roots, diminishing from spring to autumn, at first very rapidly, then slowly. The stem and roots give up to leaves in process of formation most of their nitrogenous food, and their store is replenished little by little during the season. The fats are scarce in stems or roots; they are more abundant in leaves, in which they increase from spring to autumn. Water is at a maximum in early spring and a minimum in autumn. Autumn, when the water is at a minimum and the reserve food at a maximum, is the most favorable time for the transplantation of trees. Sablon seems to have overlooked some important German work on reserve food in trees, especially that of Mueller.—C. R. B.

Bertrand[31] obtained from pure cultures of various orchids the same fungus, and found that the seeds of these species, sowed with this fungus (an Oospora?) to the exclusion of other micro-organisms, gave normal plants, regularly infested. Cypripedium seeds grown aseptically do not develop; Cattleya embryos grow to the spherule stage and no further unless then infected; *Bletia hyacinthina* develops a stem and some leaves, but does not pass this stage unless infected, when it pursues a normal course. The action of the fungus is to incite growth in cells other than those attacked. This knowledge will be useful to growers. In a discussion of tuberization Bertrand expresses the view that though tuberization is an anomaly of growth (from the morphological point of view) due to an abnormal concentration of the sap, in nature this concentration is brought about not by any of the methods of the laboratory (which have been urged as disproving this theory of tuberization), but by the attacks of endophytic fungi.—C. R. B.

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[30] Sablon, Leclerc du, Recherches physiologiques sur les matières de réserves des arbres. Rev. Gén. Bot. **16**: 341–368, 386–401. 1904.

[31] Bertrand, N., Recherches expérimentales sur les Orchidées. Rev. Gén. Bot. **16**: 458–476. *pls. 18–19.* 1904.

IT APPEARS from PORODKO's work on the growth of bacteria and molds under different pressures of oxygen,[32] that the maximum pressure of this gas which can be borne varies, in twenty-five organisms studied, from 0.676 to 9.38 atmospheres. A single nutrient medium was used throughout, and the author points out that with other media perhaps the maximal pressures might have been different. The upper limit of oxygen pressure for optimal growth seems not to be related to the maximal pressure. Furthermore, every aerobe has its specific minimal pressure of the gas. This point lies considerably higher for the molds than for bacteria, being about 0.6 atmospheres for Aspergillus, Penicillium, and Mucor, while it is 0.00016 for *Bacillus subtilis*. Of course, in case of facultative anaerobes there is no minimum. The lower limit for most obligate aerobes lies low enough to allow the growth of obligate anaerobes.—B. E. LIVINGSTON.

MISS ROBERTSON,[33] in continuing her study of *Torreya californica*, has described the sexual structures and fertilization. Two to four archegonia are produced, the neck consisting of a single tier of four or six cells. The division of the central cell was observed, and an ephemeral ventral nucleus inferred. The two male nuclei were observed in a common cytoplasmic sheath, but no inequality in the male cells was noted. In fertilization the cytoplasm of the male cell was observed investing the fusion nucleus. In the development of the proembryo wall-formation occurs after four free nuclei have appeared. A count of chromosomes indicated that the reduction number is eight. The general conclusion is reached that the morphological evidence does not bear out the suggestion of cycadean resemblances obtained from the anatomy of the seed and seedling.—J. M. C.

GRÉGOIRE[34] has investigated the reduction of chromosomes in the pollen mother-cells of *Lilium speciosum* and *Allium fistulosum*. The immediate occasion for the investigation was that STRASBURGER's recent conclusions[35] conflict with those of BERGHS,[36] a pupil of GRÉGOIRE. The present investigation convinces GRÉGOIRE that his pupil is correct in his interpretations, and that STRASBURGER's recent interpretation of mitosis in *Thalictrum purpurascens* will not apply to Lilium, Allium, and Convallaria. The most interesting observation in the present paper concerns alternations of generation. GRÉGOIRE claims that since reduction is not complete until the four spores are formed from the

[32] PORODKO, THEODOR, Studien über den Einfluss der Sauerstoffspannung auf pflanzliche Mikroorganismen. Jahrb. Wiss. Bot. **41**: 1–64. 1904.

[33] ROBERTSON, AGNES, Studies in the morphology of *Torreya californica*. II. The sexual organs and fertilization. New Phytol. **3**: 205–216. *pls. 7–9*. 1904.

[34] GRÉGOIRE, VICTOR, La réduction numérique des chromosomes et les cinèses de maturation. La Cellule **21**: 297–314. 1904.

[35] STRASBURGER, EDUARD, Ueber Reduktionsteilung. Sitzungsb. K. K. Preus. Akad. Wiss. **18**:—. [1–28.] 1904. See BOT. GAZETTE **38**: 397–398. 1904.

[36] BERGHS, JULES, La formation des chromosomes hétérotypiques dans la sporogénèse végétale I. La Cellule **21**: 173–189. 1904. See BOT. GAZETTE **38**: 228. 1904.

mother-cell, the gametophytic generation begins with the spore rather than with the spore mother-cell.—CHARLES J. CHAMBERLAIN.

BORGESEN and JENSEN[37] have given a floristic description of a portion of heath in Jutland, Denmark. On the suggestion of WARMING, a part of the estate now meadow has been reserved for experimental purposes, the object being to trace the developmental phases from cultivated soil to heath. Another portion of the heath was burned over in order to trace the progressive stages from no vegetation until the tract is again converted into the Calluna heath. Another object in view is to trace the succession of plants on areas which now are or are to be planted with conifers. The data of the present condition seem to be thoroughly detailed and classified. Hence it would seem that future observations on this tract will furnish interesting and valuable material for the ecologist.—G. H. JENSEN.

STOKLASA[38] reports the finding of lactic acid produced by the enzyme lactolase as one of the intermediate products of anaerobic respiration of gourds, beets, and potatoes, under aseptic conditions. Acetic acid and formic acids were also formed. Meanwhile BUCHNER has abandoned his contention that lactic acid is one of the intermediate products in alcoholic fermentation (with which STOKLASA absolutely identified anaerobic respiration), in the light of the researches of NEF. At the close of his paper STOKLASA hints darkly at results which indicate that chlorophyll-free plant cells form CHOH as in photosynthesis, the CO_2 being reduced by nascent H to formaldehyde, water being again formed. —C. R. B.

LIVINGSTON finds[39] that the cations of many metallic nitrates and sulfates act in the same way and at the same concentration upon Stigeoclonium, producing death at certain concentrations, causing the filamentous form to become palmelloid at lower concentrations, and sometimes at the latter concentrations, but oftener at a still lower one, accelerating in a marked degree the formation of zoospores. The palmella effect is identical with that produced by withdrawal of water, but the zoospore effect is exactly the opposite. The degree of toxicity of the metals found agrees in a general way with that found by other observers, though there are many unexplained discrepancies.—C. R. B.

ON THE BASIS of comparative researches with the quartz spectrograph, TSCHIRCH comes to the conclusion[40] that the yellow pigments of flowers and

[37] BORGESEN, —, and JENSON, —, En floristisk Undersögelse af et Stykke Hede i Vestjylland. (A floristic research on a portion of heath in West Jutland.) Bot. Tidsskrift **26**:———. 1904.

[38] STOKLASA, J., Ueber das Enzym Lactolase, welches die Milchsäurebildung in der Pflanzenzelle verursacht. Ber. Deutsch. Bot. Gesells. **22**:460–466. 1904.

[39] LIVINGSTON, B. E., Chemical stimulation of a green alga. Bull. Torr. Bot. Club **32**:1–34. *figs. 17.* 1905.

[40] TSCHIRCH, A., Vergleichend-spektralanalytische Untersuchungen, etc. Ber Deutsch. Bot. Gesells. **22**:414–439. 1904.

fruits betray no close relationship with artificial yellow pigments, a large number of both being investigated. Rather the plant pigments show alliances with the phytosterins. Carotin, he adds, probably is allied to THIELE's *fulvin*, and its chromatophore radicles contain a quinate ring of which at least three C-atoms have double bonds.—C. R. B.

VUILLEMIN[41] has published a paper on the development and structure of the membrane of the zygospore in the mucors. The main contribution of the paper is the recognition of the fact that the membrane is more complex than has usually been supposed. The author distinguished five distinct layers which differentiate successively and differ from each other in thickness, appearance, and in their behavior toward reagents. The study includes Sporodinia, Spinellus, Zygorhynchus, and Mucor.—H. HASSELBRING.

AN INVESTIGATION under the direction of PALLADIN by L. PETRASCHEVSKY[42] shows that when *Chlorothecium saccharophilum* is fed with raffinose its respiratory quotient in anaerobic life is raised much above 1 (in aerobic life it is 0.74–0.89), while with maltose it falls below the normal. Acids are probably produced as decomposition products in the former case and alcohol-like substances in the latter.—C. R. B.

CULTIVATION in a greenhouse modifies notably the external form, the habit, and the structure of plants, according to the experimental studies of BÉDÉLIAN.[43] This he ascribes to the humidity, nearly uniform temperature, and the weaker diffuse light. In general differentiation is more or less arrested, and there are manifested various adaptations to the new conditions.—C. R. B.

FRIEDEL finds the effect of insufficient oxygen on the anatomy of certain plants quite parallel with that of darkness. The relative thickness of the cortex is increased, that of the pericyclic region is diminished, and lignification is incomplete.[44] The experiments, however, cannot be continued long enough to make these effects as marked as in etiolation.—C. R. B.

KELLICOTT[45] finds in roots of Allium and Podophyllum two maxima (*c.* 11 and 1 P. M.) and two minima (*c.* 7 A. M. and 3 P. M.) in cell division, which are not affected by slight variations in temperature, but are affected by solutes in tap water. Elongation maxima and minima in Allium coincide respectively with minima and maxima in cell division.—C. R. B.

[41] VUILLEMIN, P., Recherches morphologiques et morphogéniques sur la membrane des zygospores. Ann. Mycol. **2**:483–506. *pls. 8–11.* 1904.

[42] PETRASCHEVSKY, L., Ueber Atmungscoefficienten der einzelligen Alge *Chlorothecium saccharophilum.* Ber. Deutsch. Bot. Gesells. **22**:323–327. 1904.

[43] BÉDÉLIAN, J., Influence de la culture en serre sur quelques plantes des environs de Paris. Rev. Gén. Bot. **16**:318–336. *pls. 10–13.* 1904.

[44] FRIEDEL, JEAN, Influence d'une faible pression d'oxygène sur la structure anatomique des plantes. Rev. Gén. Bot. **16**:305–317. 1904.

[45] KELLICOTT, WM. E., The daily periodicity of cell division and of elongation in the root of Allium. Bull. Torr. Bot. Club **31**:529–550. *figs. 8.* 1904.

NEWS.

DR. G. BITTER, formerly of the University of Münster, has been appointed director of the recently established Botanical Garden at Bremen.

DR. W. MIGULA, formerly at the Technical School at Carlsruhe, has been appointed professor of botany at the School of Forestry at Eisenbach.

PROFESSOR CHARLES R. BARNES, University of Chicago, sailed for Europe April 8, to be absent seven months. He will attend the International Botanical Congress at Vienna.

THE CEDAR POINT LAKE LABORATORY of the Ohio State University offers instruction in general botany and ecology from June 26 to August 4. The instructor is Otto E. JENNINGS, Carnegie Museum.

AT THE THIRD ANNUAL MEETING of the Central Branch of American Society of Naturalists and Affiliated Societies, held at Chicago March 31 and April 1, the annual address of the chairman, PROFESSOR JOHN M. COULTER, University of Chicago, was upon "Public interest in research."

THE MARINE BIOLOGICAL LABORATORY at Woods Hole, Mass., offers instruction in Thallophytes and Cell studies from June 28 to August 9, 1905. The instructors are BRADLEY MOORE DAVIS, University of Chicago; JAMES J. WOLFE, Trinity College, N. C., and ROBERT B. WYLIE, Morningside College, Iowa.

THE BOTANICAL SOCIETY of the Netherlands has begun the publication of its *Archives* in two parts. The title of one is *Nederlandsch Kruidkundig Archief*, dealing with the Dutch flora and printed in Dutch; that of the other is *Recueil des travaux botaniques Néerlandais*, dealing with subjects of more general interest.

THE BERMUDA BIOLOGICAL STATION FOR RESEARCH will be open in 1905 under the direction of Professor E. L. MARK, of Harvard University, and Professor C. L. BRISTOL, of New York University. Botanists who wish to take advantage of the station must apply not later than May 1. The date of sailing from New York is July 1 and six weeks will be spent at the station.

WITH ITS January number the *Indian Forester* commences its thirty-first volume with a great improvement in appearance. In typography, size, and contents the subscription price (12*s* 6*d*) is exceedingly low. While the journal devotes considerable space to the discussion of forest problems that confront the Forest Service in India, it discusses problems of much wider scope and is of general interest to all students of forestry.

THE AMERICAN MYCOLOGICAL SOCIETY met in affiliation with the A. A. A. S. at Philadelphia, December 28 to 31. The following officers were elected: President, CHARLES H. PECK; Vice-President, F. S. EARLE; Secretary-treasurer, C. L. SHEAR; and the following committee on organization and relation to the other societies was appointed: C. L. SHEAR, S. M. TRACY, and ROLAND THAXTER. The following program was presented: Suggestions for the study of dairy fungi, CHARLES THOM; A new disease of the cultivated agave, GEORGE G. HEDGCOCK; A study of North American Coleosporiaceae, and The terminology of the spore-structures in the Uredinales, J. C. ARTHUR; Classification of the Geoglossaceae, E. J. DURAND; Generic characters of North American Thelephoraceae, E. A. Burt; Cultures of wood-inhabiting fungi, PERLEY SPAULDING; Two fungous parasites on mushrooms, and The genus Balansia in the United States, G. F. ATKINSON.

THE "BOTANISTS of the Central States" met at the University of Chicago, March 31 and April 1, in connection with the Central Branch of the American Society of Naturalists, with STANLEY COULTER, of Purdue University, as chairman, and CHAS. F. MILLSPAUGH, of the Field Columbian Museum, as secretary. The following papers were read and discussed:

C. F. HOTTES, University of Illinois, The effect of starvation on the cells of the root tip; W. B. MCCALLUM, University of Chicago, Regeneration and polarity in the higher plants; R. H. POND, Northwestern University, The endosperm enzyme of *Phoenix dactylifera;* E. W. OLIVE, University of Wisconsin, Nuclear and cell division in certain lower plants; E. O. JORDAN, University of Chicago, A rosette-forming micro-organism; F. M. LYON, University of Chicago, Development of the megaspore coats of Selaginella; R. A. HARPER, University of Wisconsin, The nuclear fusion in the ascus, and alternation of generations in the Ascomycetes; A. H. CHRISTMAN, University of Wisconsin, Sexual reproduction in the rusts; B. M. DAVIS, University of Chicago, The sexual organs of the Rhodophyceae and Uredinales; C. J. CHAMBERLAIN, University of Chicago, Apogamy and apospory in ferns; E. B. SIMONS, University of Chicago, The morphology and development of the conceptacle in Sargassum; J. B. OVERTON, University of Wisconsin, The permanence of the chromosomes and their behavior in synapsis; C. F. MILLSPAUGH, Field Columbian Museum, Recent field-work in the Bahamas.

A permanent organization of the society was effected, with WILLIAM TRELEASE, Missouri Botanic Garden, as president, and H. C. COWLES, University of Chicago, as secretary-treasurer.